Carderock Division, Naval Surface Warfare Center

Silver Spring, Maryland 20903-5640

CARDIVNSWC/TR-94/018 1 October 1994

Materials Directorate

Research and Development report

Sorption and Diffusion of Moisture in Multilayer Composite AEM/S System Sandwich Material

by

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Sorption and diffusion of Moisture in Multilayer Composite AEMS/S System Sandwich Materials

CARDIVNSWC/TR-94/018

FOREWORD

The work described herein was conducted to support the materials development portion of the Advanced Enclosed Mast/Sensor (AEM/S) System Program. The work was sponsored by the Office of Naval Research. It was administered by Mr. Ivan Caplan, Materials Block Manager, at the Carderock Division of the Naval Surface Warfare Center (CDNSWC), Code 1225, under the Ship Submarine Materials Program (SC2B), Composite Materials Project (RS34S56), and CDNSWC Work Unit 1-6440-613.

The specific purpose of this work was to determine the moisture diffusion coefficients and solubilities of various constituent materials that may be used in ship mast sandwich constructions. These data are necessary for predicting the moisture uptake and internal distribution in these materials when they are exposed to marine environments or to accelerated aging conditions in the laboratory. Equations for obtaining these coefficients for any temperature of interest are provided. This data representation serves as input for finite element (FE) modeling of various environmental exposure scenarios. This FE effort is described in CARDIVNSWC-TR-94/019 (in preparation).

Approved by:

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ABSTRACT

The moisture diffusion coefficients and solubilities of Advanced Enclosed Mast/Sensor (AEM/S) System sandwich constituent materials of interest have been determined at 22, 35, and 50°C and at 80 percent relative humidity. Expressions for calculating the diffusion coefficients and solubilities for any temperature of typical marine environments or for accelerated laboratory aging studies are provided. The objective of this study was to provide input data for finite element moisture diffusion analyses that permits one to predict the moisture take-up and internal distribution as a function of time for composite mast or other shipboard sandwich structures in specified marine environments. The following materials were included in this investigation: E-glass/SP Systems 3113 epoxy, E-glass/510A vinyl-ester (RTM3), E-glass/G10 epoxy, Balsa wood type D57, PVC-foam (Klegecell), and Nomex honeycomb phenolic core material.

CONTENTS

Page

INTRODUCTION 1

EXPERIMENTAL 2
MATERIALS AND SPECIMEN PREPARATION 2
DETERMINATION OF DIFFUSION COEFFICIENTS 3

DISCUSSION 4
MOISTURE DIFFUSION IN COMPOSITES AND SANDWICH CONSTRUCTIONS 4
MEASUREMENT OF THE MOISTURE DIFFUSION COEFFICIENTS 5
DATA REDUCTION 6

RESULTS 8

CONCLUSIONS 10

REFERENCES 39

APPENDIX--EXPERIMENTAL DATA A-1

DISTRIBUTION . . . . (1)

ILLUSTRATIONS

Figure		Page
1	MOISTURE SORPTION IN 3113 GLASS-EPOXY FACE SHEET AT 22°C AND 80 PERCENT RH	10
2	MOISTURE SORPTION IN 3113 GLASS-EPOXY FACE SHEET AT 35°C AND 80 PERCENT RH	11
3	MOISTURE SORPTION IN 3113 GLASS-EPOXY FACE SHEET AT 50°C AND 80 PERCENT RH	12
4	MAXIMUM MOISTRUE SOLUBILITY IN 3113 GLASS-EPOXY FACE SHEET AT 80 PERCENT RH AS A FUNCTION OF TEMPERATURE	13
5	ARRHENIUS PLOT OF LOG(D) VERSUS 1/°T AT 80 PERCENT RH FOR 3113 GLASS-EPOXY FACE SHEET.	14
6	MOISTURE SORPTION IN RTM3 FACE SHEET AT 22°C AND 80 PERCENT RH.	15
7	MOISTURE SORPTION IN RTM3 FACE SHEET AT 35°C AND 80 PERCENT RH.	16
8	MOISTURE SORPTION IN RTM3 FACE SHEET AT 50°C AND 80 PERCENT RH.	17
9	MAXIMUM MOISTURE SOLUBILITY IN RTM3 FACE SHEET AT 80 PERCENT RH AS A FUNCTION OF TEMPERATUR	18
10	ARRHENIUS PLOT OF LOG(D) VERSUS 1/°T AT 80 PERCENT RH FOR RTM3 FACE SHEET	19
11	MOISTURE SORPTION IN GLASS-EPOXY COPPER EMBEDMENT SHEET (WITHOUT COPPER SCREEN) AT 22°C AND 80 PERCENT RH.	20
12	MOISTURE SORPTION IN GLASS-EPOXY COPPER EMBEDMENT SHEET (WITHOUT COPPER SCREEN) AT 35°C AND 80 PERCENT RH.	21

ILLUSTRATIONS (Cont.)

Figure		Page
13	MOISTURE SORPTION IN GLASS-EPOXY COPPER EMBEDMENT SHEET (WITHOUT COPPER SCREEN) AT 50°C AND 80 PERCENT RH	22
14	MAXIMUM MOISTURE SOLUBILITY IN GLASS-EPOXY COPPER EMBEDMENT SHEET (WITHOUT COPPER SCREEN) AT 80 PERCENT RH AS A FUNCTION OF TEMPERATURE	23
15	ARRHENIUS PLOT OF LOG(D) VERSUS 1/°T AT 80 PERCENT RH FOR THE GLASS-EPOXY COOPER EMBEDMENT SHEET (WITHOUT COPPER SCREEN)	24
16	MOISTURE SORPTION IN BALSA WOOD CORE AT 22°C AND 80 PERCENT RH	25
17	MOISTURE SORPTION IN BALSA WOOD CORE AT 35°C AND 80 PERCENT RH	26
18	MOISTURE SORPTION IN BALSA WOOD CORE AT 50°C AND 80 PERCENT RH	27
19	MAXIMUM MOISTURE SOLUBILITY IN BALSA WOOD CORE AT 80 PERCENT RH AS A FUNCTION OF TEMPERATURE	28
20	ARRHENIUS PLOT OF LOG(D) VERSUS 1/°T AT 80 PERCENT RH FOR BALSA WOOD CORE	29
21	MOISTURE SORPTION IN PVC-FOAM CORE AT 22°C AND 80 PERCENT RH	30
22	MOISTURE SORPTION IN PVC-FOAM CORE AT 50°C AND 80 PERCENT RH	31
23	MAXIMUM MOISTURE SOLUBILITY IN PVC-FOAM CORE AT 80 PERCENT RH AS A FUNCTION OF TEMPERATURE	32
24	ARRHENIUS PLOT OF LOG(D) VERSUS 1/°T AT 80 PERCENT RH FOR PVC-FOAM CORE	33
25	MOISTURE SORPTION IN HONEYCOMB CORE AT 22°C AND 80 PERCENT RH	34

ILLUSTRATIONS (Cont.)

Figure		Page
26	MOISTURE SORPTION IN HONEYCOMB CORE AT 50°C AND 80 PERCENT RH	35
27	MAXIMUM MOISTURE SOLUBILITY IN HONEYCOMB CORE AT 80 PERCENT RH AS A FUNCTION OF TEMPERATURE	36
28	ARRHENIUS PLOT OF LOG(D) VERSUS 1/°T AT 80 PERCENT RH FOR HONEYCOMB CORE	37

INTRODUCTION

The work described in this report was conducted to support the materials development portion of the Advanced Enclosure Mast/Sensors (AEM/S) System Program in which a ship mast structure that encloses critical shipboard equipment and radars is being developed.

The use of organic matrix composite sandwich constructions for Navy shipboard mast structures is a new concept which has many advantages. Although composite materials have found many applications such as structural members in Navy Aircraft (e.g. the AV8B Harrier) or missile motor cases where they are of vital importance, the use for mast structures is new. Having no prior experience with structures for this type of application also leaves many unanswered questions. After having designed and tested such a structure, there is always a concern about the longterm performance in a rather harsh marine environment. This may range from tropical to arctic climates combined with high relative humidity. Since large composite structures require both strength and stiffness at a minimum weight, sandwich constructions are frequently used for this purpose. At the same time, however, the complexity of the structure increases. More than one material has to be combined to provide the required properties. Therefore, the changes of these properties must be predictable to ensure that, over the life-time of the structure, the expected requirements, such as mechanical properties or electromagnetic responses, are met. Moisture is usually a culprit for material degradation. Thus, one needs to know, how much moisture will penetrate such a structure as a function of time, and what will be the consequences. The only way to answer these questions is to first, predict what the internal distribution of moisture will be at a given time, and second, to determine how this moisture affects the mechanical and physical properties. The purpose of this work was first to provide the input data (moisture solubilities and diffusion coefficients) necessary to model the moisture transport in such structures, and second, to actually predict the internal moisture distribution in specific sandwich materials for a marine environment over the entire expected life-time of a naval vessel. The first objective is presented in this report, the second, a finite element modeling of the moisture transport in such sandwich constructions, is described in a subsequent report.

Another purpose of this work is to provide the materials and test engineers with information on how to prepare test panels and specimens, using accelerated aging conditions. Test specimens for full life-time predictions of moisture penetration or worst case scenarios can then easily be prepared.

This report will provide the moisture solubilities of face sheet and core materials as a function of temperature between room temperature and 50°C and the diffusion coefficients and their temperature dependence at maximum moisture concentrations corresponding to 80 percent relative humidity (RH).

EXPERIMENTAL

MATERIALS AND SPECIMEN PREPARATION

The following AEM/S System materials were obtained from CDNSWC, Annapolis: E-glass/epoxy (SP Systems 3113); E-glass/vinyl-ester (510A), (RTM3); E-glass/epoxy (G10); Balsa wood type D57 AL6000 [nominally 7 lb./ft.^{3}, manufactured by Baltec U.S.A]; PVC-foam [Klegecell II (R75), is a polyvinyl chloride (PVC) foam, of a nominal density of 4.7 lb./ft.^{3}, manufactured by Polymex Corp., Italy], and Nomex honeycomb phenolic core material. For brevity, we will call these materials: 3113, RTM3, G10, Balsa wood, PVC-foam and honeycomb repectively. They were cut into rectangular specimens. Dimensions are given for all specimens in the Appendix. The thickness of each specimen was measured with a micrometer at nine different places and the average was taken for the computation of the diffusion coefficient. These samples were thoroughly dried at 100 to 105°C in a vacuum oven for at least one week before they were exposed to their respective temperature/humidity conditions. For the moisture sorption experiments, the samples were placed into a preheated desiccator above a saturated KCl salt bath (with undissolved salt) to provide the desired 80 percent RH. The samples were periodically removed from the desiccator to determine their weight gain.

The data for all the sorption experiments are given in the Appendix. Each table includes the material name; the environmental conditions (°C and RH); the sample ID; the length, width, and thickness of each sample; the sampling times (in minutes); their corresponding weights; the maximum moisture uptake at the respective exposure conditions; the values for the respective M_t/M_∞; the values for (time/thickness^2)$^{1/2}$ [in (sec/cm^2)$^{1/2}$]; the results of the linear regression of the initial data (up to 0.55 of M_t/M_∞); the average diffusion coefficients (for infinitely extended plates and for the corrected finite specimen dimensions).

The maximum moisture solubilities were defined as the weight differences between the dried and the fully saturated specimens (when no further weight gain could be observed) at a given temperature. The empirical relation of the moisture solubility as a function of temperature (at 80% RH) was obtained by using a second order regression analysis. The parameters describing this curve are listed in the Appendix.

The data are plotted as M_t/M_∞ versus (time/thickness^2)$^{1/2}$. The experimental points were graphed by connecting the individual points with straight lines. No attempt was made to draw smooth curves, since only the initial straight line portion of the curve was used for determining the diffusion coefficient. Furthermore, Arrhenius plots of log D versus 1/T (in degree Kelvin) are given.

DETERMINATION OF DIFFUSION COEFFICIENTS

The diffusion coefficients were determined as described under the heading DATA REDUCTION on page 7.

DISCUSSION

MOISTURE DIFFUSION IN COMPOSITES AND SANDWICH CONSTRUCTIONS

The purpose of this work is to determine the moisture diffusion coefficients and solubilities in multilayered composite sandwich materials to be used for shipboard structures. Specifically, it is necessary to determine these properties for each constituent material in the temperature range of interest for a marine environment. For a number of reasons it is desirable to know the moisture transport and internal distribution in such structures. For instance, the mechanical properties may change in moisture loaded materials or the radar transmission may be affected. If one wants to predict the moisture distribution at every part of the structure (in a given environment, i.e., temperature and humidity) throughout its life-time, or if one wants to prepare test panels of these materials with a desired moisture content, one needs to know the diffusion coefficient of these materials as a function of temperature and humidity. We have shown previously that the diffusion coefficient of void-free composite laminates can be calculated if the diffusion coefficients of the neat resin and that of the fiber are known together with the fiber volume fraction.[1] However, we have also demonstrated that such predictions of the diffusion coefficient for porous composites, as obtained by filament winding, will give rather large errors. Therefore, it is better to determine the diffusion coefficients for composites directly.[2,3] For layered structures, where the different layers have different diffusion coefficients, one can calculate an overall diffusion coefficient as described by Crank which is analogous to the electrical resistivity in series (Equation 1)[4]

$$\frac{l}{D} = \frac{l_1}{D_1} + \frac{l_2}{D_2} + \ldots\ldots \frac{l_n}{D_n} \tag{1}$$

where $l_1, l_2, \ldots l_n$ are the thicknesses of the various layers, l is the total thickness, $D_1, D_2, \ldots D_n$ are the diffusion coefficients of the individual layers and D is the overall diffusion coefficient. This formula is useful if one only wants to determine the permeation through the layered structure but is less suitable if one wants to determine the internal moisture distribution through the layered structure as a function of time. In such cases, one can calculate the internal moisture distribution by a finite difference or a finite element analysis. Such analyses will be discussed in a forthcoming technical report.

The approach taken was to determine the diffusion coefficients, the maximum moisture solubilities, and their respective temperature dependences of all materials that are presently of interest for use in the REM/S System.

In the literature, one finds examples for increasing, decreasing, and constant diffusion coefficients as a function of moisture concentration.[5,6] This difference in diffusion behavior was explained by the strength of the interaction of the diffusant with the solute. If, for instance, there are

hydrophilic groups in the polymer which interact with the diffusing water molecule, D increases with increasing moisture concentration. However, when the water concentration is high enough that water molecules can cluster with each other, then D decreases again, i.e., there may be a maximum in the curve of D as a function of concentration. On the other hand, the solution of water in hydrophobic polyolefins is quite ideal thermodynamically and the mobility factor is independent of concentration, which leads to a constant D.

In general, the temperature dependence of D follows the empirical equation:

$$D = D_0 \exp(-E_D / RT) f(c) \tag{2}$$

where E_D is the mean activation energy, R is the ideal gas constant, T the absolute temperature in °K and f(c) can be expressed as a function of concentration c, or volume fraction ϕ, or activity a in the form $\exp(\alpha c)$, etc. For a small temperature range, these functions are essentially one and the equation for D becomes:

$$D = D_0 \exp(-E_D / RT) \tag{3}$$

Since diffusion is a thermally activated process, the Arrhenius relation was used to predict the diffusion coefficients for all other temperatures which are valid for such thermally activated processes. The apparent activation energy is obtained from the slope of the straight line when log(D) is plotted vs. 1/T. Therefore the diffusion coefficients were measured at 22, 35, and 50° C.

For a more detailed diffusion analysis, it would also be desirable to know the concentration dependence of the diffusion coefficients, however, the effort to do that would be about 3 times as much and was not justifiable at the present time. Since a maritime environment is around 80% RH, and, since in many cases the moisture diffusion coefficient at lower RH value is lower, the error made by assuming a concentration independent diffusion coefficient will be on the conservative side. This means, in the interior of the composite, where the concentration is lower than at the surface (before the maximum moisture level is attained) the diffusion coefficient is still considered to be as high as on the surface.

MEASUREMENT OF THE MOISTURE DIFFUSION COEFFICIENTS

There are several methods of measuring the diffusion coefficients of gases in solid materials.[4] Some are based on direct permeation measurements through a thin membrane or a slice of the solid. In such experiments the permeating gas is measured directly by the change in pressure or by gas chromatography. Sorption experiments usually measure the change in pressure of the gas being absorbed or desorbed from a specimen where the geometry is suitable for an analytical solution. Instead of measuring the change in partial pressure of the diffusing gas, the sorbed gas can also be measured gravimetrically, as we have done in this work.

The samples were exposed at 80 percent RH and at constant temperature (22, 35 and 50°C to ±1°C) in desiccators over a KCl solution which contained undissolved salt to maintain a constant RH. The weight gain of each sample was determined gravimetrically, in discrete time steps, by removing the samples periodically and weighing them at room temperature with a semi-micro-balance.

The diffusion coefficient measurements in composites is straight forward and quite accurate. The sample size was nominally 0.1" by 2" by 2". For the core materials (PVC-foams, Balsa wood, and honeycomb core), one expects to have a much higher moisture transport. Therefore, the samples had to be much thicker. The experimental accuracy of the measurements on core materials for the elevated temperatures are expected to be lower because of some moisture loss during the time of removal from the constant RH container and weighing. This operation has to be done in as short a time as possible. Also, the sample-to-sample variations of the core materials are higher than with composites. In contrast to PVC foam (which has closed pores) the other core materials have open channels for an even more rapid moisture transport. Yet, one can still determine an effective diffusion coefficient, because the sorption of moisture into the solid core material requires time until full saturation is attained. Also, the amount of sorbed moisture can be much higher than that of the face sheet composites (about 14 weight percent for Balsa wood). Since the diffusion coefficients of the core materials is much higher than the composite face sheets however, one does not need an accurate diffusion coefficient of the core material if one wants to model the through-the-thickness moisture diffusion. As we will show in a subsequent report, even if the diffusion coefficient of the core material were 1000 times higher than what was actually measured, it would not make a significant difference in the moisture distribution with time.

More important than the diffusion coefficient is the maximum solubility of moisture in the core material because the solubility is analogous to the heat capacity in thermal conductivity problems. For intance, Balsa wood, having a high moisture solubility will reach total moisture saturation after a much longer time than a core with low solubility such as a PVC foam core. These effects will be discussed in the forthcoming report which describes the modeling of the moisture transport through the sandwich wall structure using finite difference and finite element analyses.

DATA REDUCTION

Determination of the Moisture Diffusion Coefficient in Plates of Finite Dimensions

The basic solution for Fick's diffusion equation for vapors in an infinite membrane is given by Crank[4] [Equation (3)]

$$\frac{M_t}{M_\infty} = 1 - \sum_{n=0}^{\infty} \frac{8}{(2n+1)^2 \pi^2} e^{-D(2n+1)^2 \pi^2 t/4l^2} \tag{4}$$

where M_t denotes the total amount of diffusing substance which has entered the sheet at time t, and M_∞ the corresponding quantity after infinite time. The thickness of the membrane extends from $-l$

to $+l$.

The initial slope of this curve (up to about 0.55), for all practical purposes, follows a straight line, from which one can obtain the diffusion coefficient, and Equation (4) then simplifies to Equation (5)

$$\frac{M_t}{M_\infty} = \frac{4}{\pi^{1/2}} \left[\frac{Dt}{(th)^2} \right]^{1/2} \tag{5}$$

where (th) denotes the thickness of the sheet. If the initial gradient, $R = d(M_t / M_\infty)/d(t/(th)^2)^{1/2}$, is observed in a sorption experiment in which D is the concentration-dependent diffusion coefficient, then the average diffusion coefficient, $\bar{D}$, is given by Equation (6)

$$\bar{D} = \pi R^2/16. \tag{6}$$

The data were plotted as M_t / M_∞ versus $[t/(th)^2]^{1/2}$. The initial slope of these curves was obtained from a least square fit of the data points from 0 to 0.55. (The number of points used for the analysis varied, depending of how many points could be obtained below the value of 0.55). This average diffusion coefficient was then corrected for the open edges as described by Rothwell and Marshall.[7] The equation derived by these authors is [Equation (7)]

$$\frac{D}{D_0} = \frac{(1+\frac{h}{a}+\frac{h}{b})^2}{[(1+\frac{h}{a}+\frac{h}{b})^2 - \frac{3}{4}(\frac{h}{a}+\frac{h}{b}+\frac{h^2}{ab})F_1]^2} \tag{7}$$

where D_0 is the uncorrected diffusion coefficient, D is the corrected, h is the specimen thickness, a the length, b the width, and F_1 has the value of 0.7.

RESULTS

The following AEM/S materials, obtained from NSWC/CD, Annapolis, were investigated: two outside face-sheet materials (a vinyl ester E-glass fiber reinforced plastic, designated here as RTM3, and another E-glass fiber SP Systems 3113 epoxy composite, designated as 3113), an interior glass fiber epoxy composite (designated as G10) which can contain a copper grid of various geometries, and 3 core materials (designated as Balsa wood, PVC-foam, and honeycomb core materials). The glass epoxy material was measured without the thin flat copper grid which serves special electromagnetic purposes. This special copper grid, consisting of a thin flat foil with a special geometric pattern which reduces the effective diffusion cross section. It is not necessary to measure the diffusion coefficient for each geometry, as long as the cross-sectional grid area is known. The diffusion coefficient of this material is reduced proportional to the area of the copper (in analogous to electrical conduction with parallel resistors).

Experimental data presented in the appendix include the results obtained from sorption measurements at 80 percent RH and at 22, 35, and 50°C. Given are the sample dimensions, their exposure times and their respective weight gains, the values of M_t/M_∞ versus $[\text{time/thickness}^2]^{1/2}$, the maximum moisture solubilities (for 80 percent RH), and the edge-corrected diffusion coefficients. Coefficients for the mathematical expression to determine the average diffusion coefficients and solubilities for any temperature of interest, are given in the summary sheet page A-3. These coefficients were used for the comparison of the measured and calculated average diffusion coefficients and solubilities listed on page A-3. The material densities were calculated from the measured sample geometry. The apparent activation energies of diffusion were calculated from the slope of the experimental data of the average diffusion coefficients plotted as log(D) versus 1/T according to Equation (3).

A visual presentation of the experimental data is given in Figures 1 through 28. The experimental data points are connected with straight, solid lines without attempting to put smooth curves through them. The graphs for the regression analyses of the maximum moisture solubilities also show dotted curves which represent the expressions for the averages calculated from second order regression analysis. The dotted lines of the Arrhenius plots however, are straight lines, since it is assumed that in the small temperature interval from 22 to 50°C there is no change in the diffusion mechanism and the Arrhenius behavior is maintained.

Figures 1 to 3 show the sorption data of the 3113 epoxy face sheet composite (plotted as M_t/M_∞ versus $(\text{time/thichness}^2)^{1/2}$) at 22, 35, and 50°C and 80 percent RH. Figure 4 shows the maximum moisture solubility of this material at 80 percent RH between room temperature and 50°C. Figure 5 gives the temperature dependence of the diffusion coefficient, the dotted line indicating the average. Figures 6 through 10 show the same results for the RTM3 vinyl ester face sheet. Note that the RTM3 material has a lower moisture solubility but a higher diffusion coefficient than the 3113 epoxy composite. Figures 11 through 15 show the sorption behavior of the internal copper screen glass fiber embedment layer. The copper screen was not included since the optimal geometry of the

etched copper mask was unavailable at the time of the measurement. However, this is of little importance, since for this thin copper foil one can easily calculate the diffusion coefficient for any geometry of the copper screen. The surface through which moisture can diffuse is the area not covered by the copper screen. Thus, the diffusion coefficient measured above is to be multiplied by $(1 - f_{Cu})$, where f_{Cu} is the fractional area of the copper screen. Figures 16 through 20 show the sorption results for the Balsa wood core material. As mentioned before, Balsa wood sorption measurements by gravimetry is less accurate, especially at elevated temperature, because moisture can desorb much more rapidly during the weight measurements. The samples were taken from the warm humidity chamber and its weight was immediately determined to 5 decimal places (instead of 6 as used for the composites). As mentioned before, even a very large error in the diffusion coefficient of the core material would not show any measurable difference in the overall diffusion and moisture distribution, as long as the moisture has to pass through the face sheet, i.e. as long as there is not damage or diffusion from the edges of the sandwich material. The reason for this is that the face sheet dominates the overall transport of moisture into the interior. The sorption behavior of the PVC core was determined at 22 and 50°C and is shown in Figures 21 through 24. The results for the Nomex honeycomb core are shown in Figures 25 through 28. Again, the accuracy of these core materials is of little importance since they are so much higher than that of the face sheet materials. One needs to remember that the time to reach an overall moisture equilibrium depends on the maximum solubility of the core material rather than its diffusion coefficient. The effect of damage to the face sheet material needs further investigation.

These sorption and diffusion coefficients will be used in a finite difference and a finite element analysis to model the moisture uptake and the internal distribution of various sandwich constructions for the AEM/S Sandwich Materials and test panels.

CONCLUSIONS

The moisture diffusion coefficients, solubilities, and densities of E-glass/SP Systems 3113 epoxy, E-glass/510A vinyl-ester (RTM3), E-glass/G10 epoxy, Balsa wood type D57, PVC-foam (Klegecell), and Nomex honeycomb phenolic core materials have been determined gravimetrically at 22, 35, and 50°C and at 80 percent RH.

These data are sufficient for obtaining a mathematical expression to predict the average diffusion coefficients and solubilities for typical marine environments of interest to the Navy and can be used to model the uptake of moisture and its internal distribution in AEM/S System sandwich constructions by using finite element or finite difference diffusion codes.

Thus, any combination of the above listed materials with any thicknesses as well as the inclusion of metal screen materials with different geometries can be modeled for their internal moisture distribution as a function of time. Examples of some specific combinations of sandwich constructions and modeling of moisture diffusion by finite element analysis will be discussed in a forthcoming technical report.

All objectives of this study have been met.

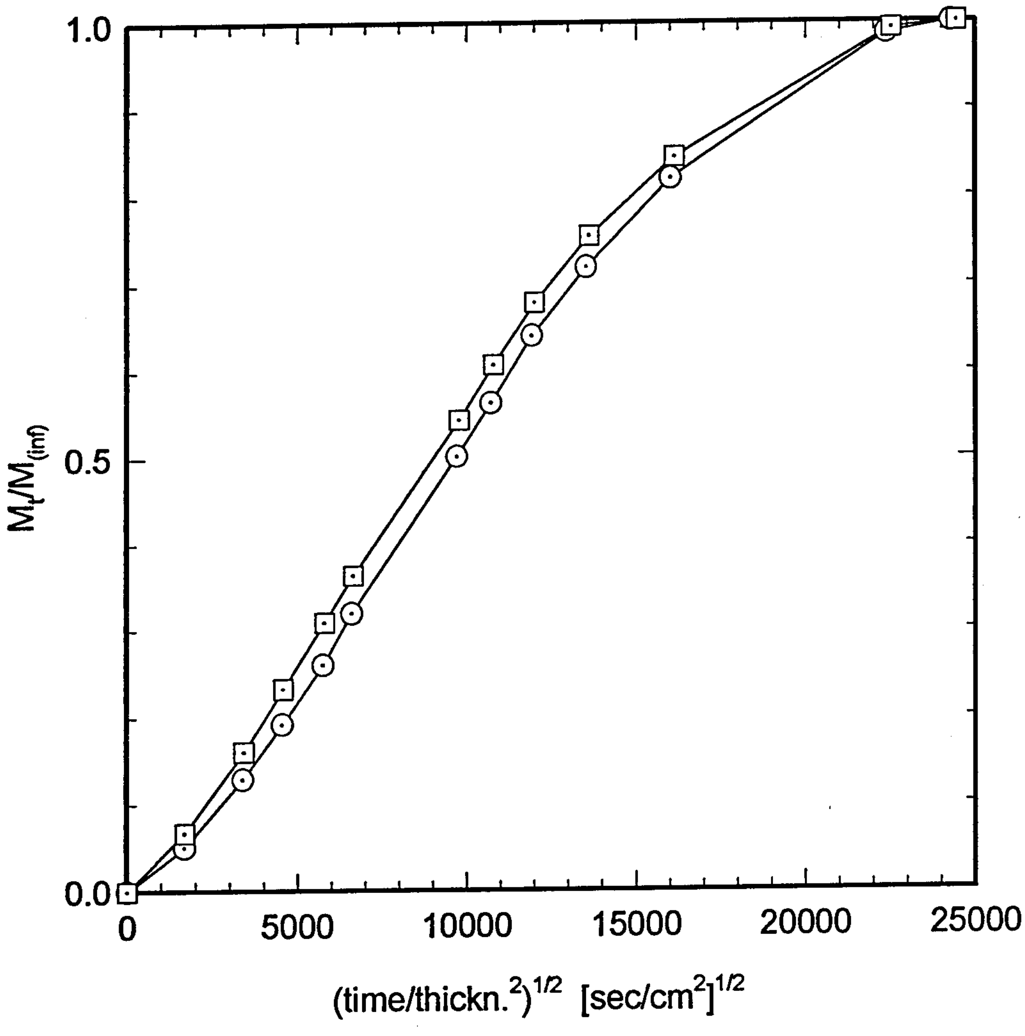

FIGURE 1. MOISTURE SORPTION IN 3113 GLASS-EPOXY FACE SHEET AT 22°C AND 80 PERCENT RH

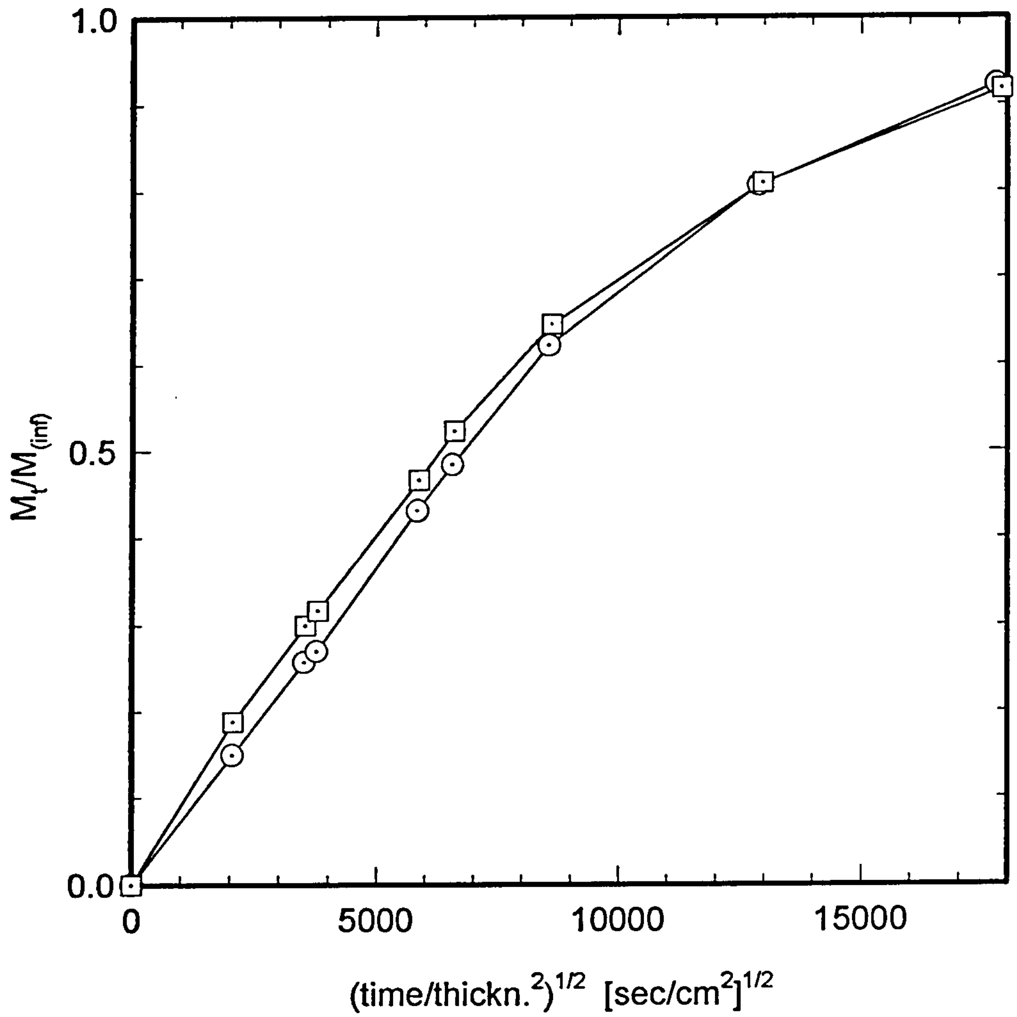

FIGURE 2. MOISTURE SORPTION IN 3113 GLASS-EPOXY FACE SHEET AT 35°C AND 80 PERCENT RH

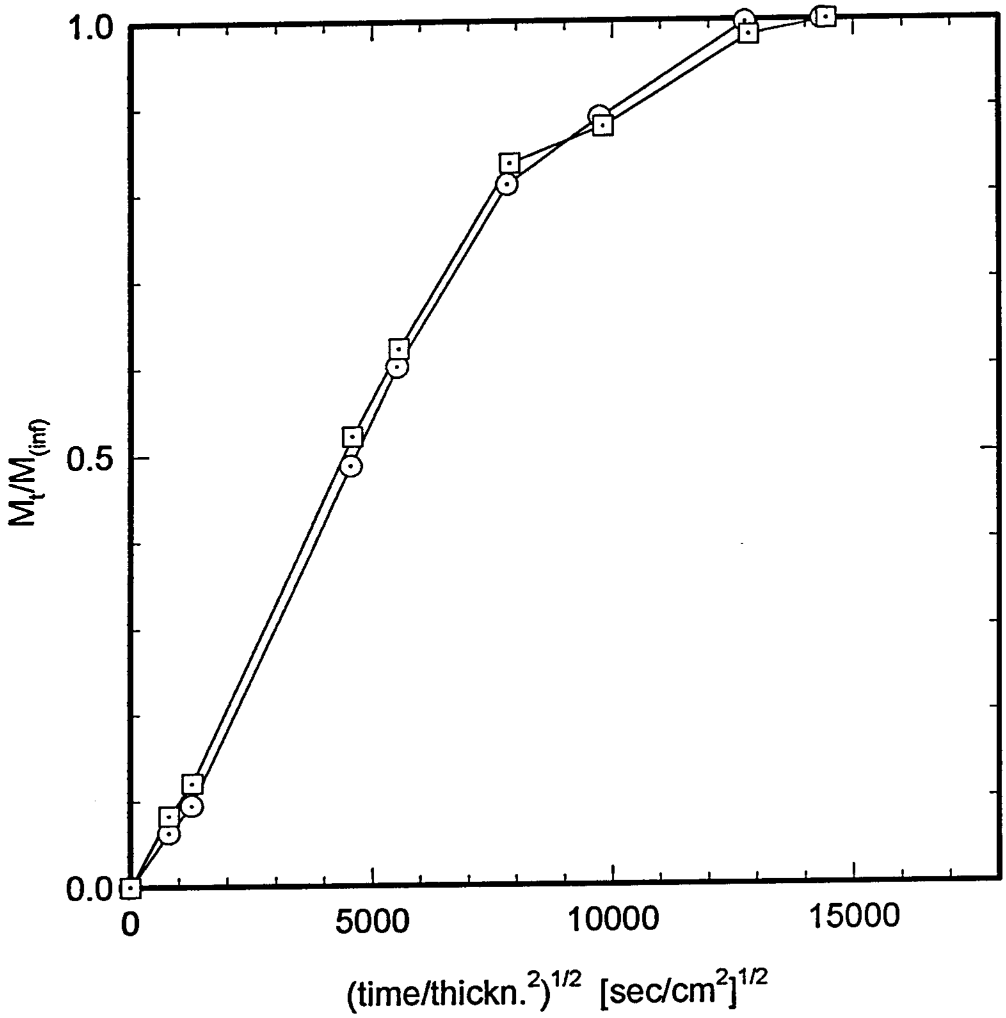

FIGURE 3. MOISTURE SORPTION IN 3113 GLASS-EPOXY FACE SHEET AT 50°C AND 80 PERCENT RH

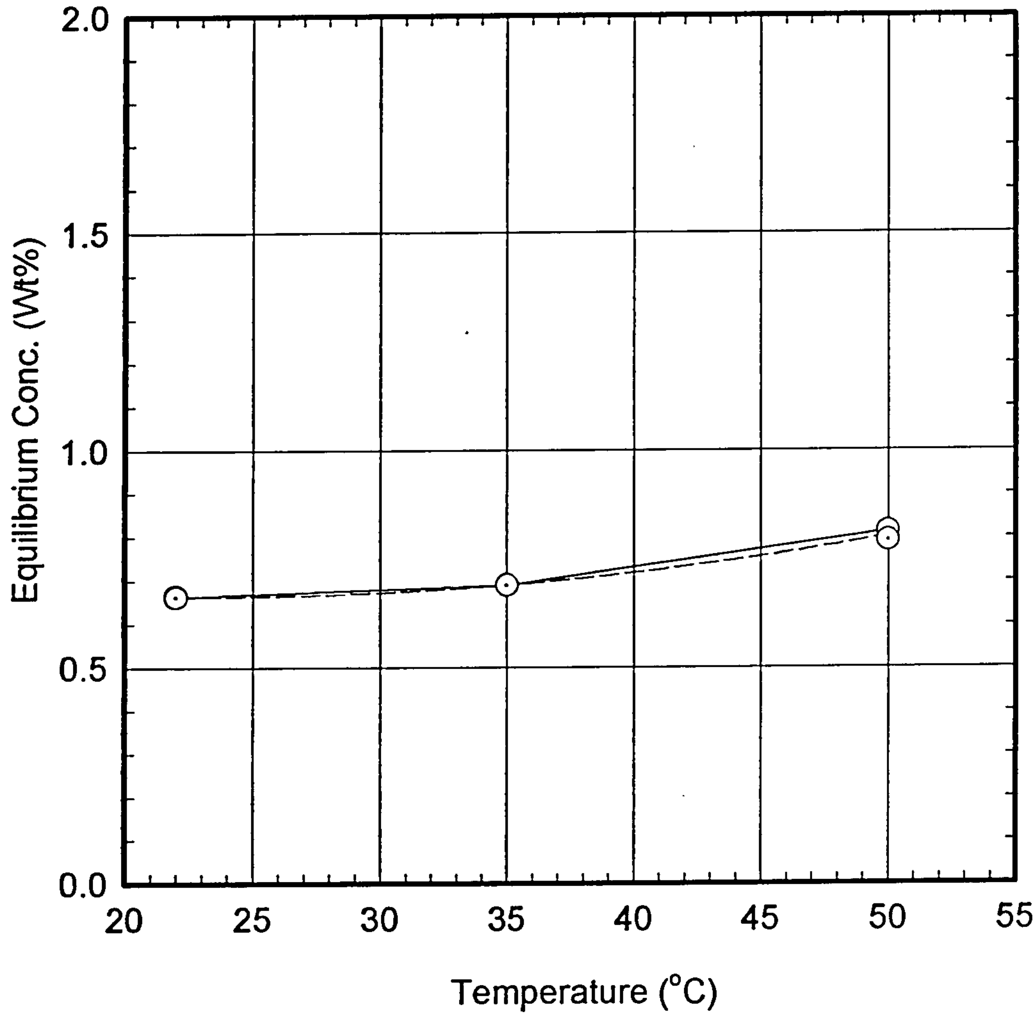

FIGURE 4. MAXIMUM MOISTRUE SOLUBILITY IN 3113 GLASS-EPOXY FACE SHEET AT 80 PERCENT RH AS A FUNCTION OF TEMPERATURE

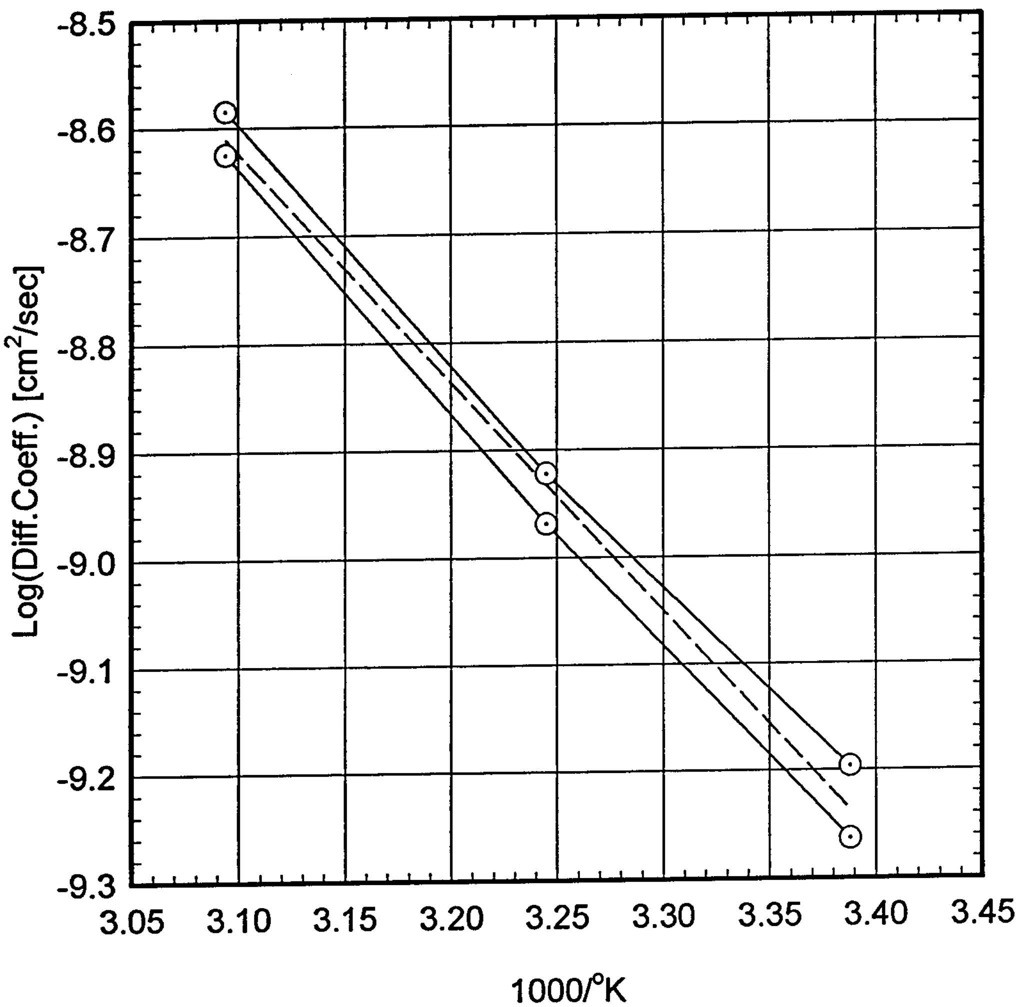

FIGURE 5. ARRHENIUS PLOT OF LOG(D) VERSUS 1/°T AT 80 PERCENT RH FOR 3113 GLASS-EPOXY FACE SHEET

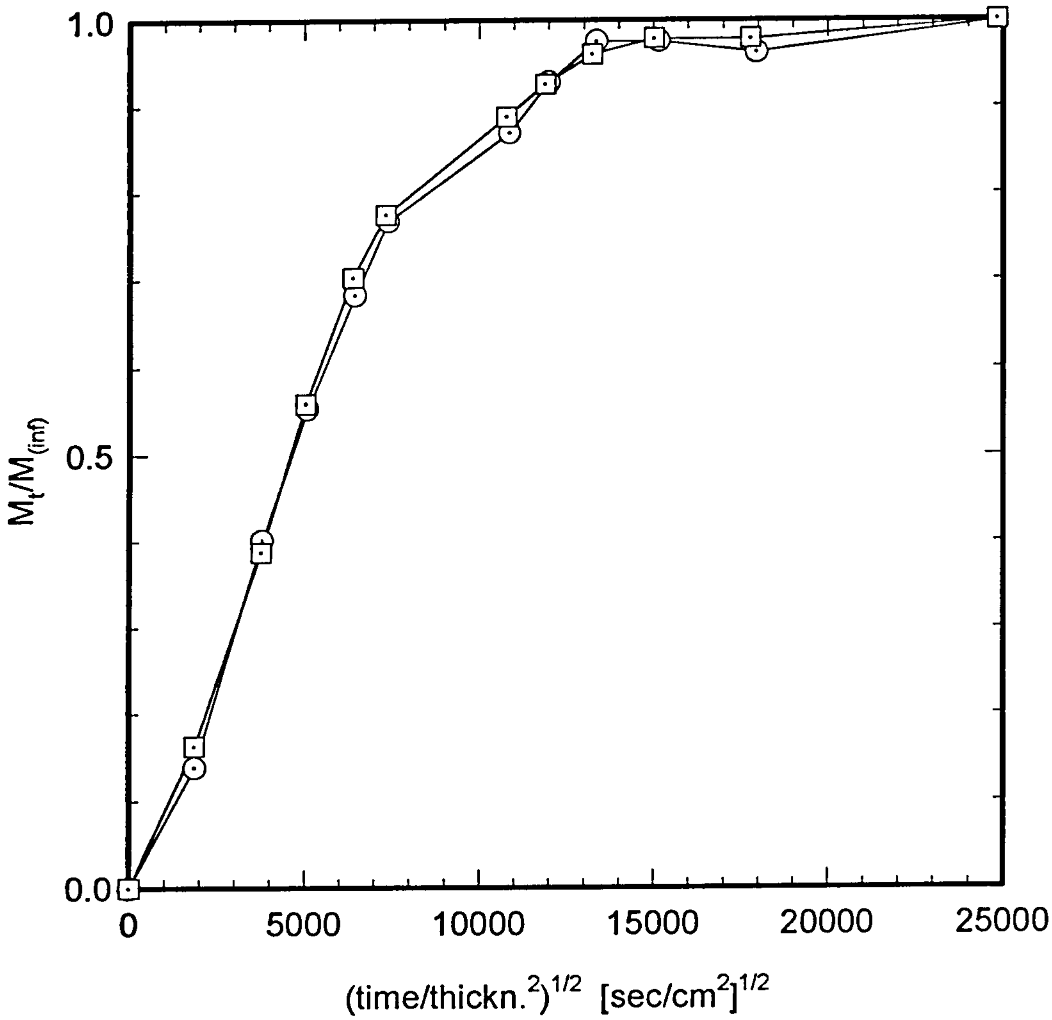

FIGURE 6. MOISTURE SORPTION IN RTM3 FACE SHEET AT 22°C AND 80 PERCENT RH

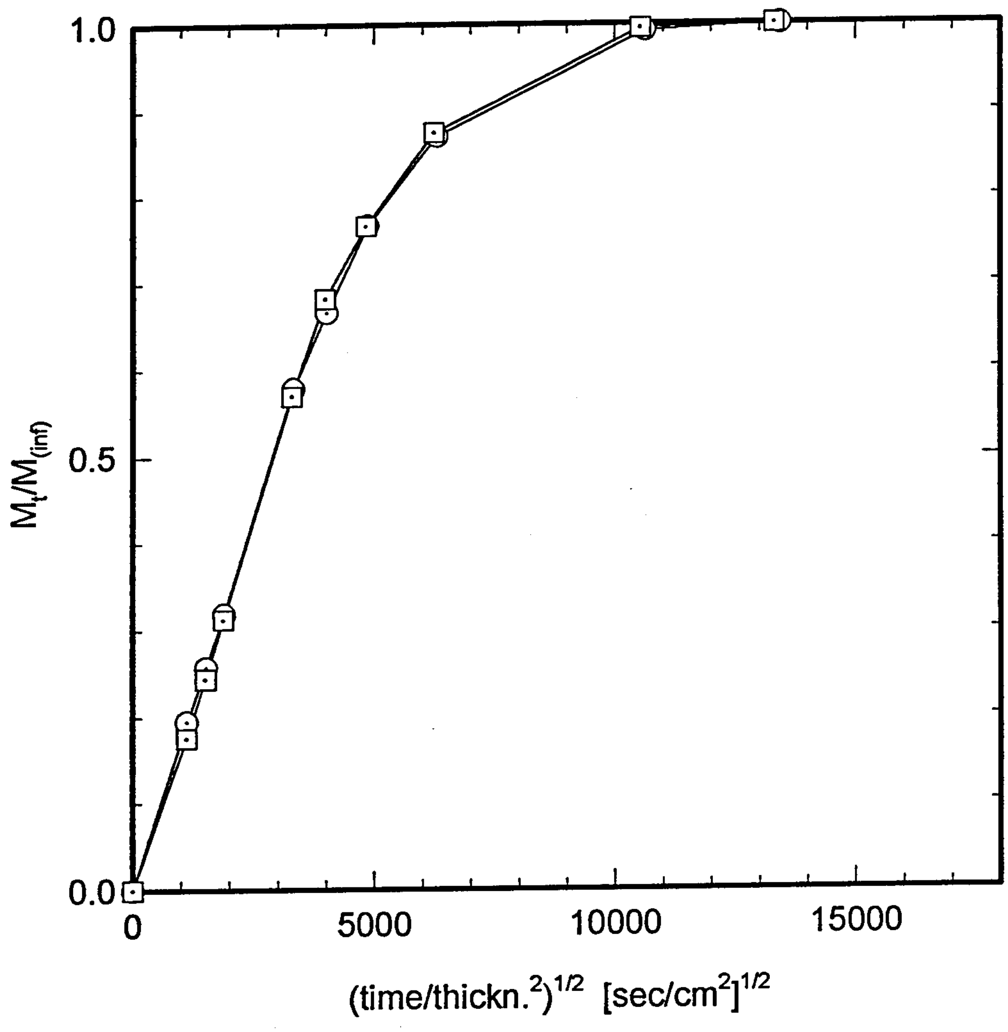

FIGURE 7. MOISTURE SORPTION IN RTM3 FACE SHEET AT 35°C AND 80 PERCENT RH

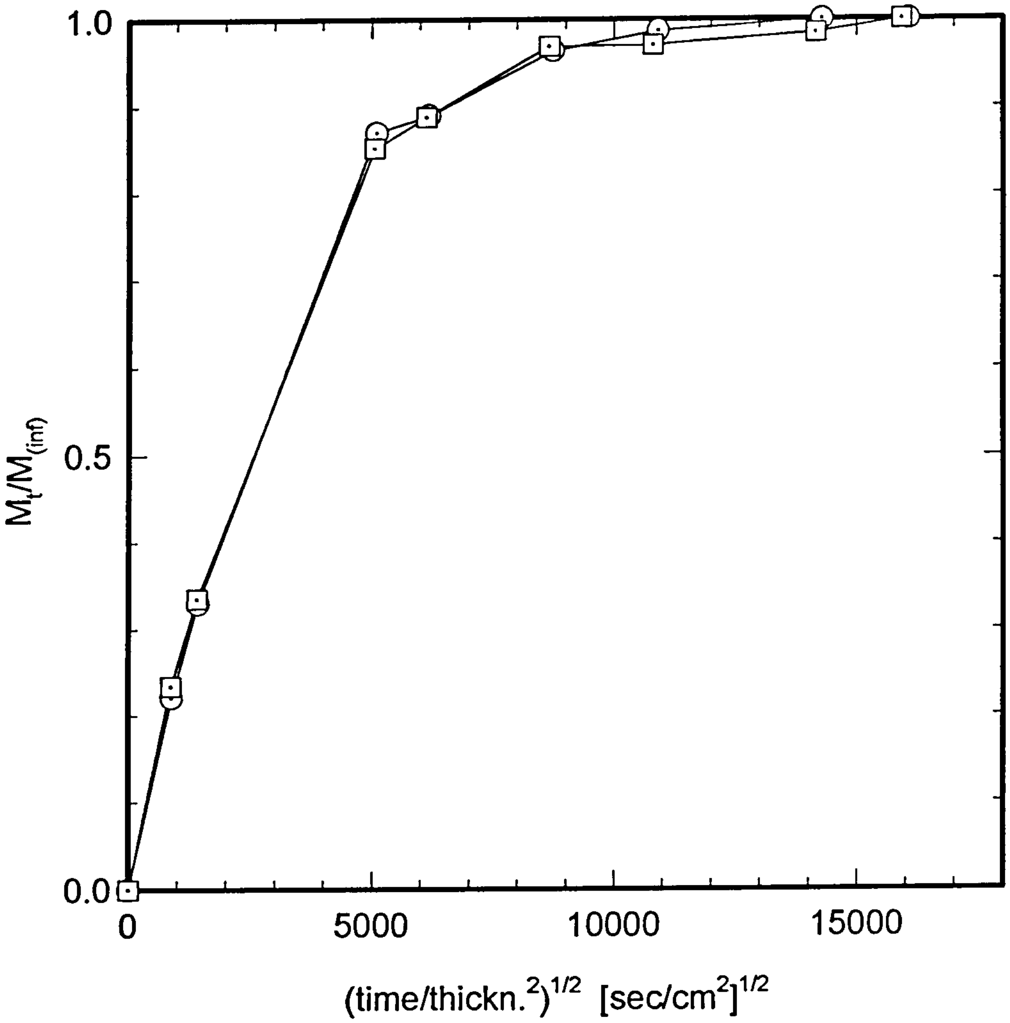

FIGURE 8. MOISTURE SORPTION IN RTM3 FACE SHEET AT 50°C AND 80 PERCENT RH

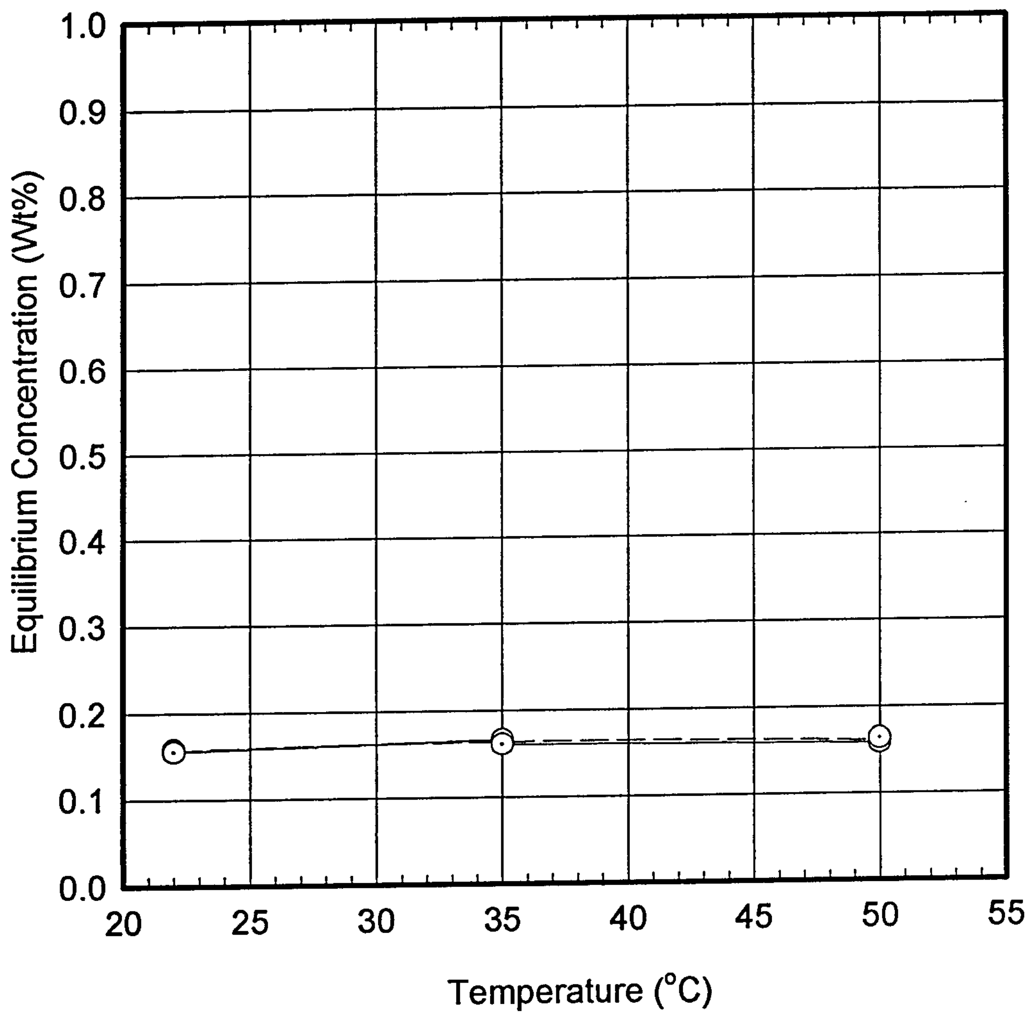

FIGURE 9. MAXIMUM MOISTURE SOLUBILITY IN RTM3 FACE SHEET AT 80 PERCENT RH AS A FUNCTION OF TEMPERATURE

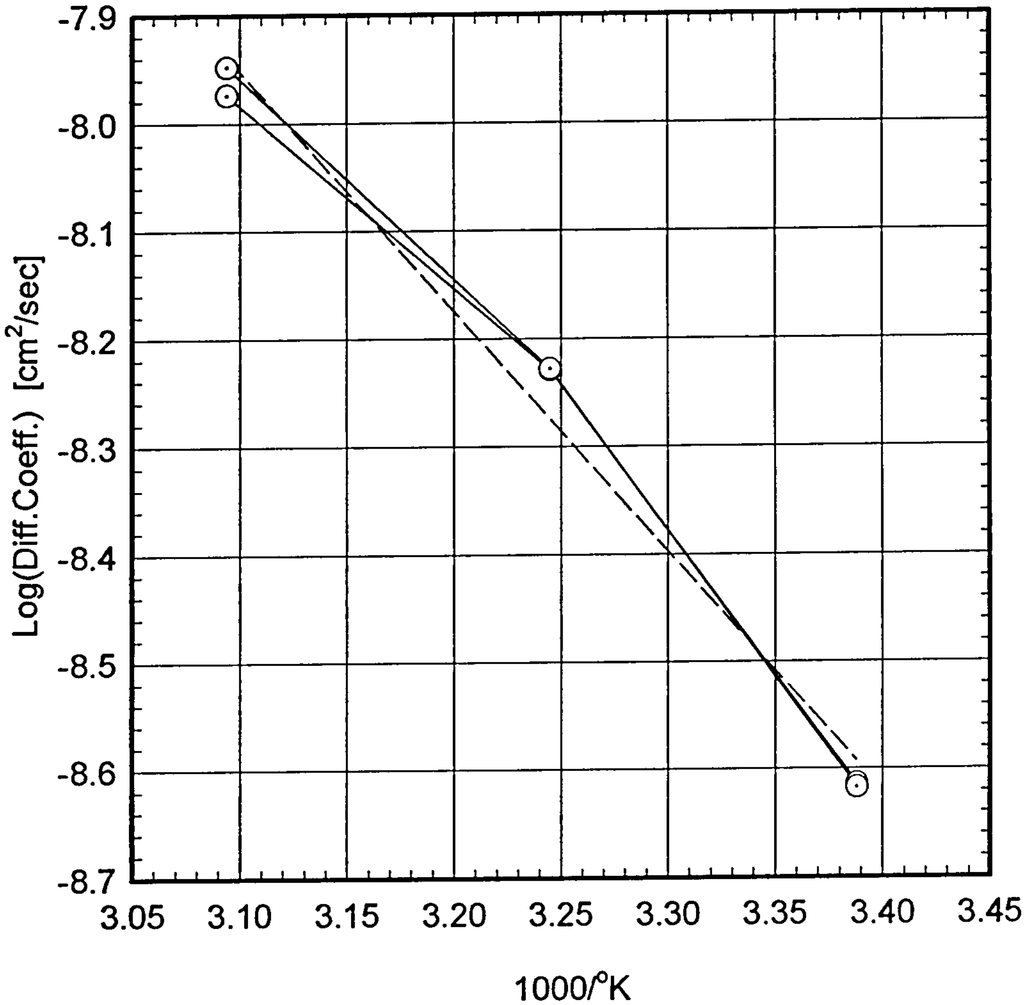

FIGURE 10. ARRHENIUS PLOT OF LOG(D) VERSUS 1/°T AT 80 PERCENT RH FOR RTM3 FACE SHEET

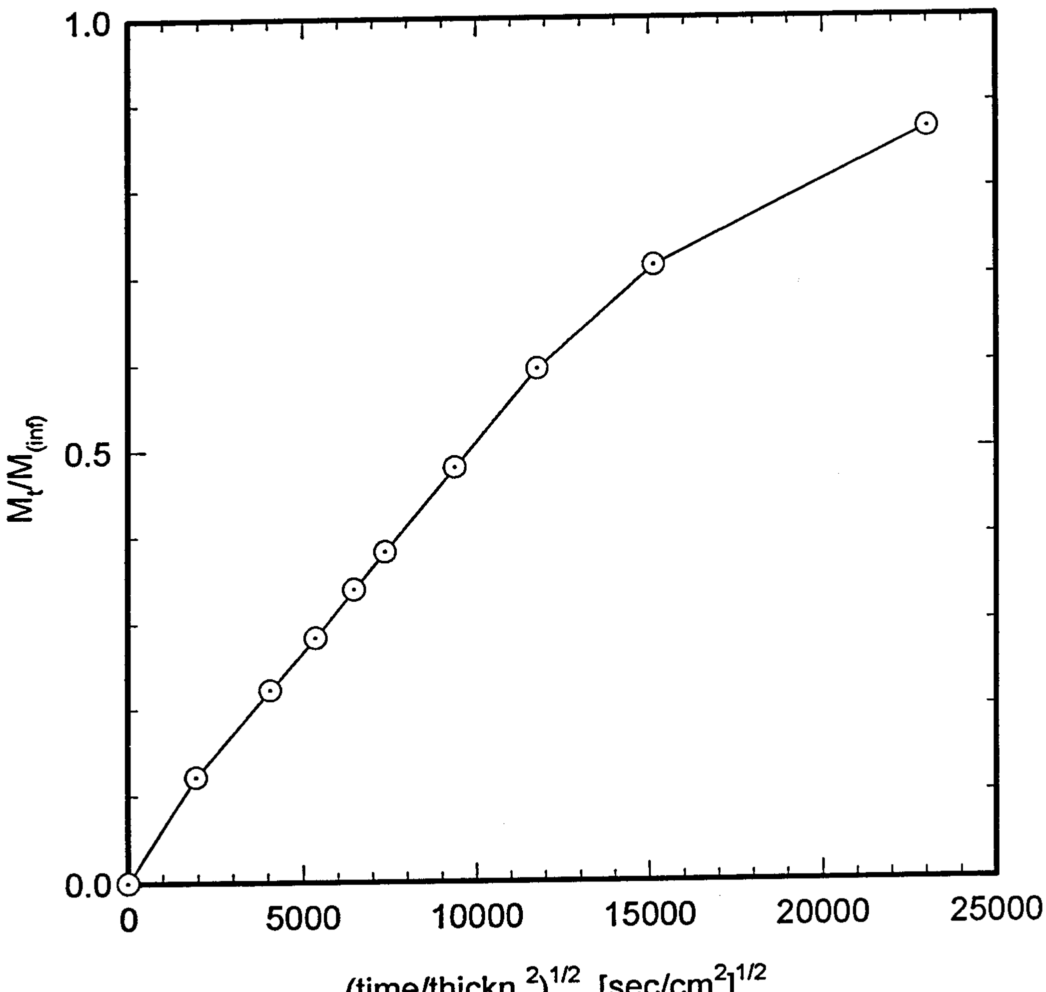

FIGURE 11. MOISTURE SORPTION IN GLASS-EPOXY COPPER EMBEDMENT SHEET (WITHOUT COPPER SCREEN) AT 22°C AND 80 PERCENT RH

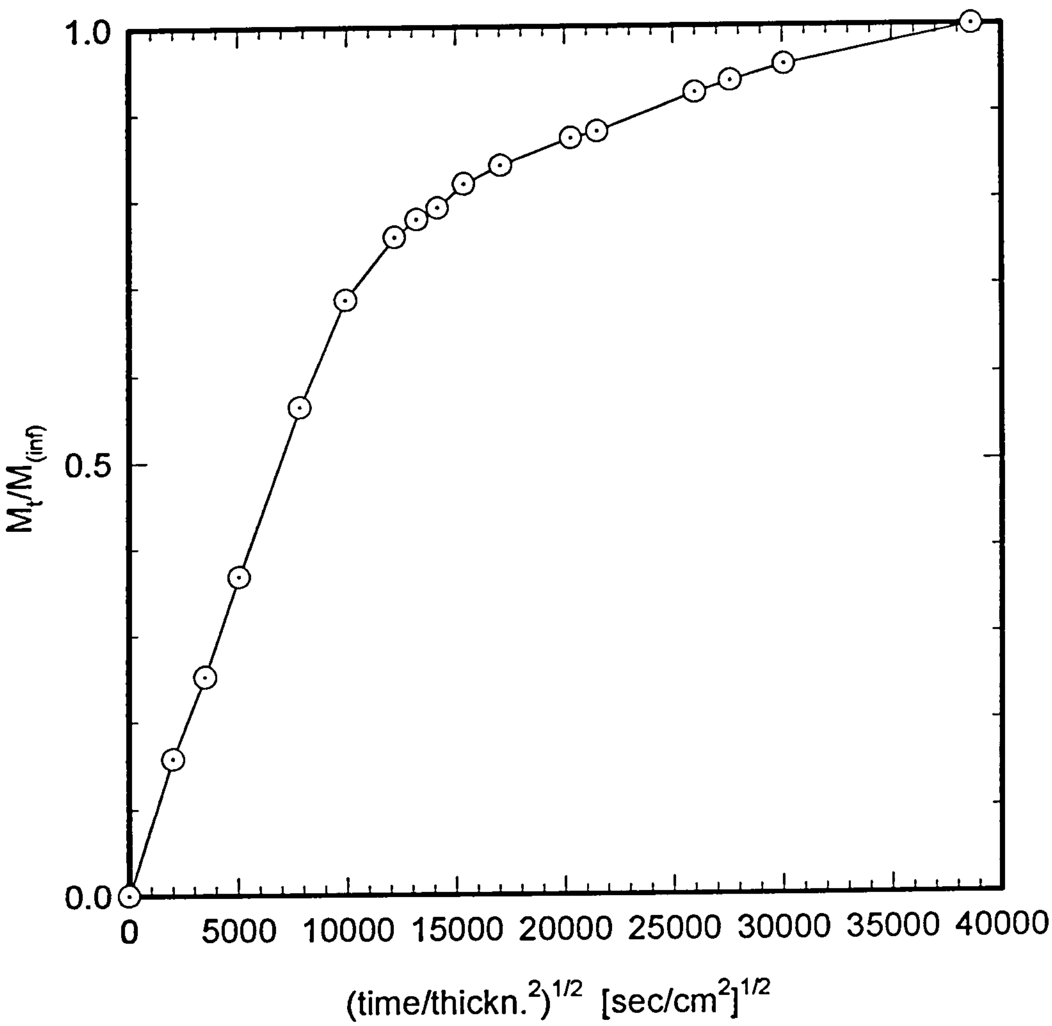

FIGURE 12. MOISTURE SORPTION IN GLASS-EPOXY COPPER EMBEDMENT SHEET (WITHOUT COPPER SCREEN) AT 35°C AND 80 PERCENT RH

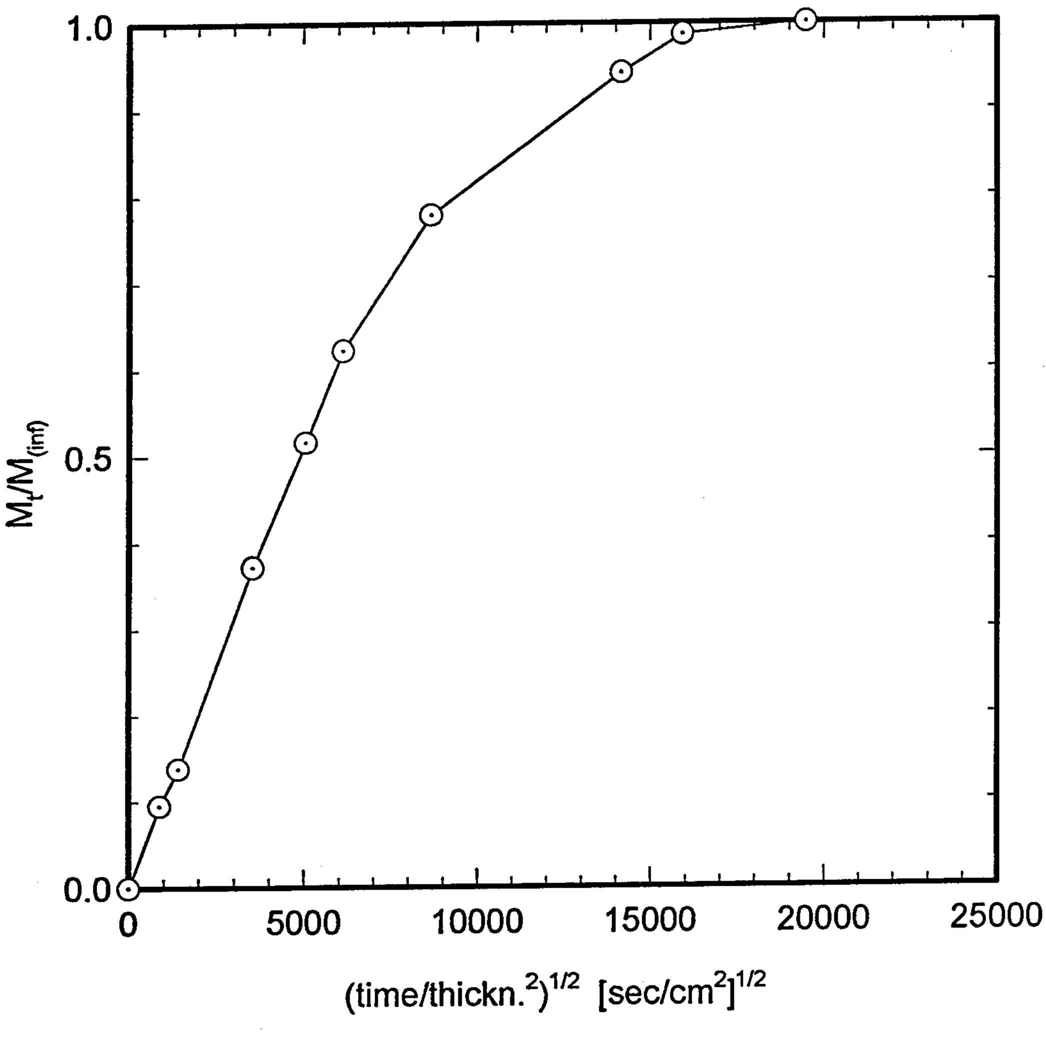

FIGURE 13. MOISTURE SORPTION IN GLASS-EPOXY COPPER EMBEDMENT SHEET (WITHOUT COPPER SCREEN) AT 50°C AND 80 PERCENT RH

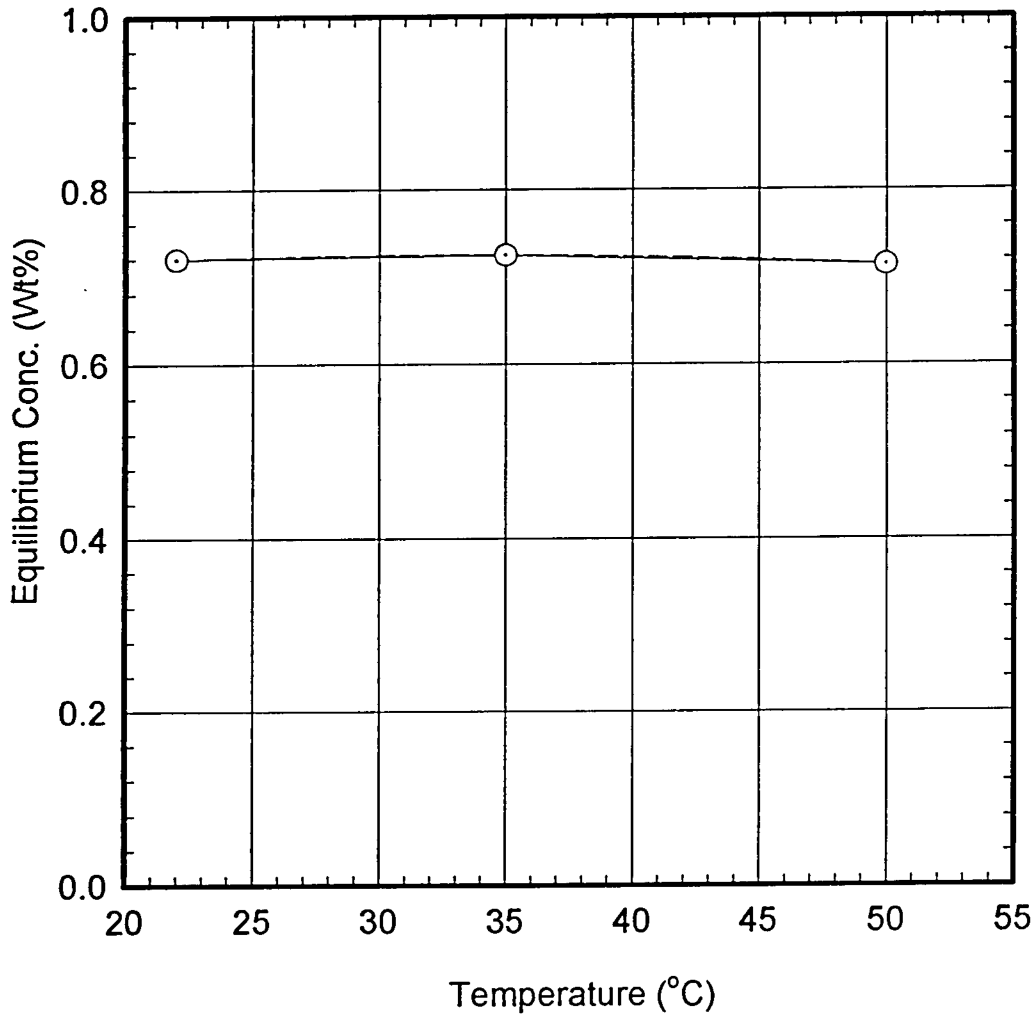

FIGURE 14. MAXIMUM MOISTURE SOLUBILITY IN GLASS-EPOXY COPPER EMBEDMENT SHEET (WITHOUT COPPER SCREEN) AT 80 PERCENT RH AS A FUNCTION OF TEMPERATURE

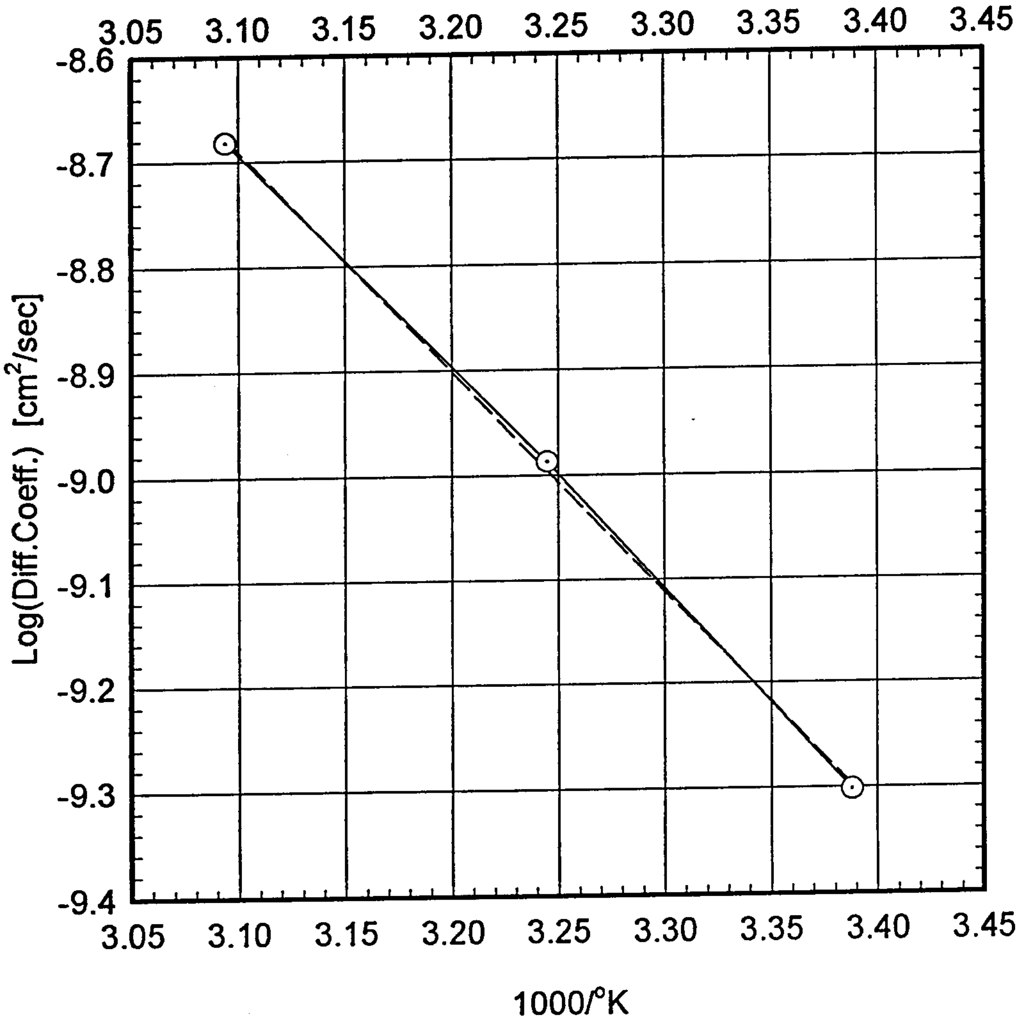

FIGURE 15. ARRHENIUS PLOT OF LOG(D) VERSUS 1/°T AT 80 PERCENT RH FOR THE GLASS-EPOXY COOPER EMBEDMENT SHEET (WITHOUT COPPER SCREEN)

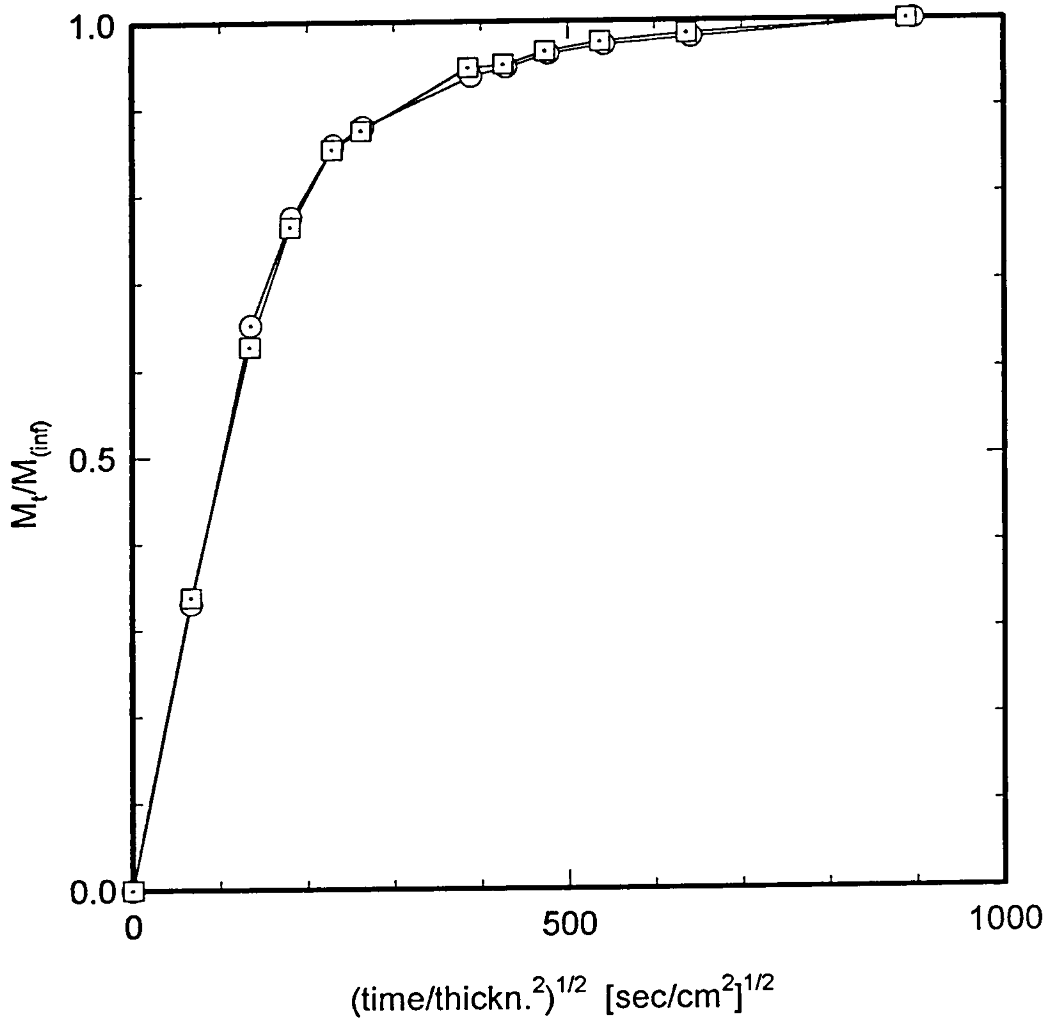

FIGURE 16. MOISTURE SORPTION IN BALSA WOOD CORE AT 22°C AND 80 PERCENT RH

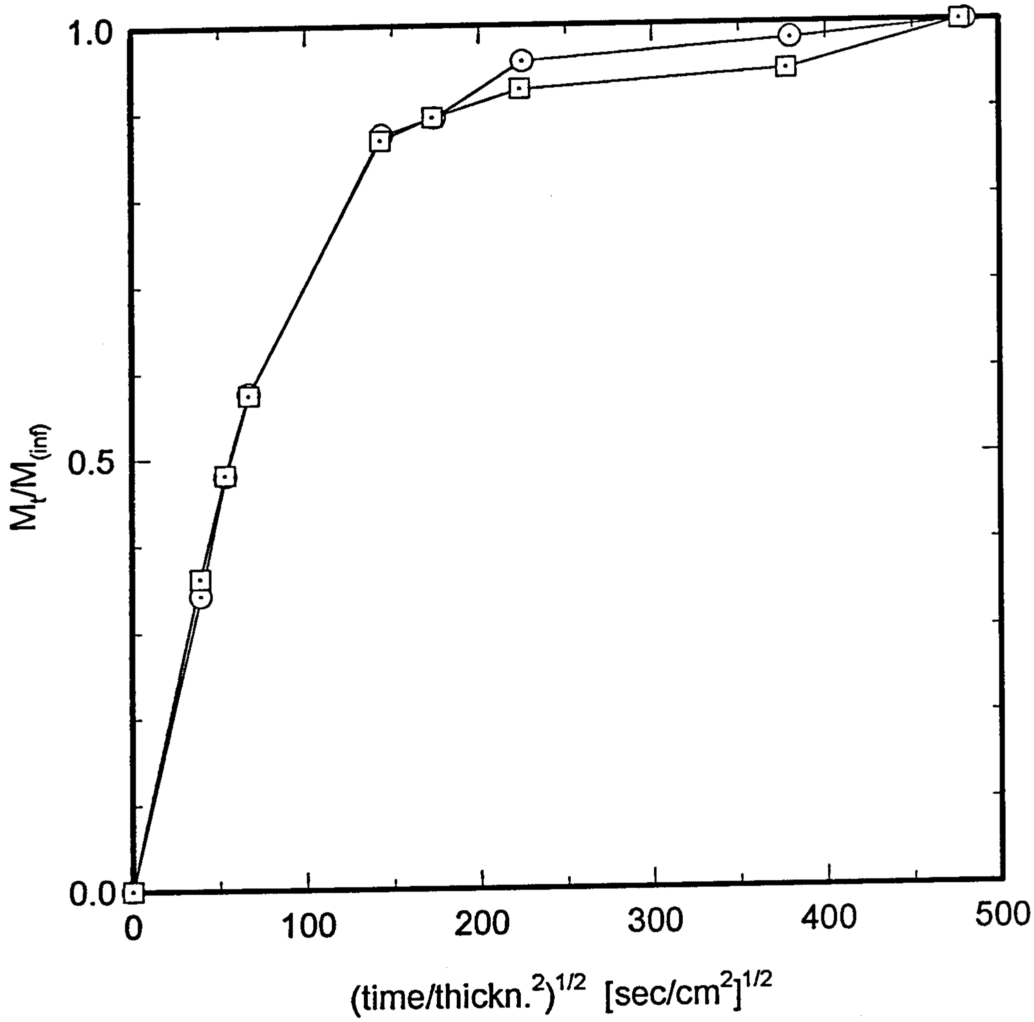

FIGURE 17. MOISTURE SORPTION IN BALSA WOOD CORE AT 35°C AND 80 PERCENT RH

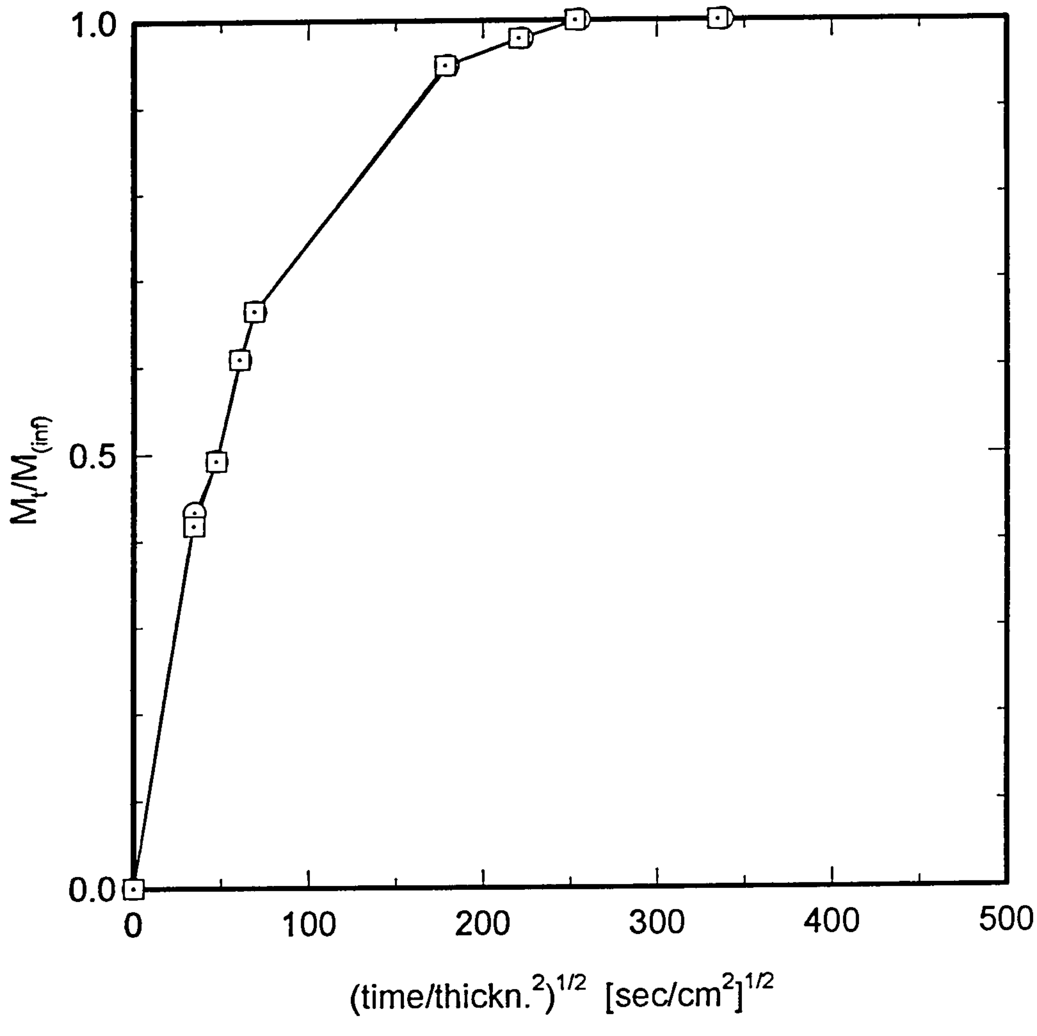

FIGURE 18. MOISTURE SORPTION IN BALSA WOOD CORE AT 50°C AND 80 PERCENT RH

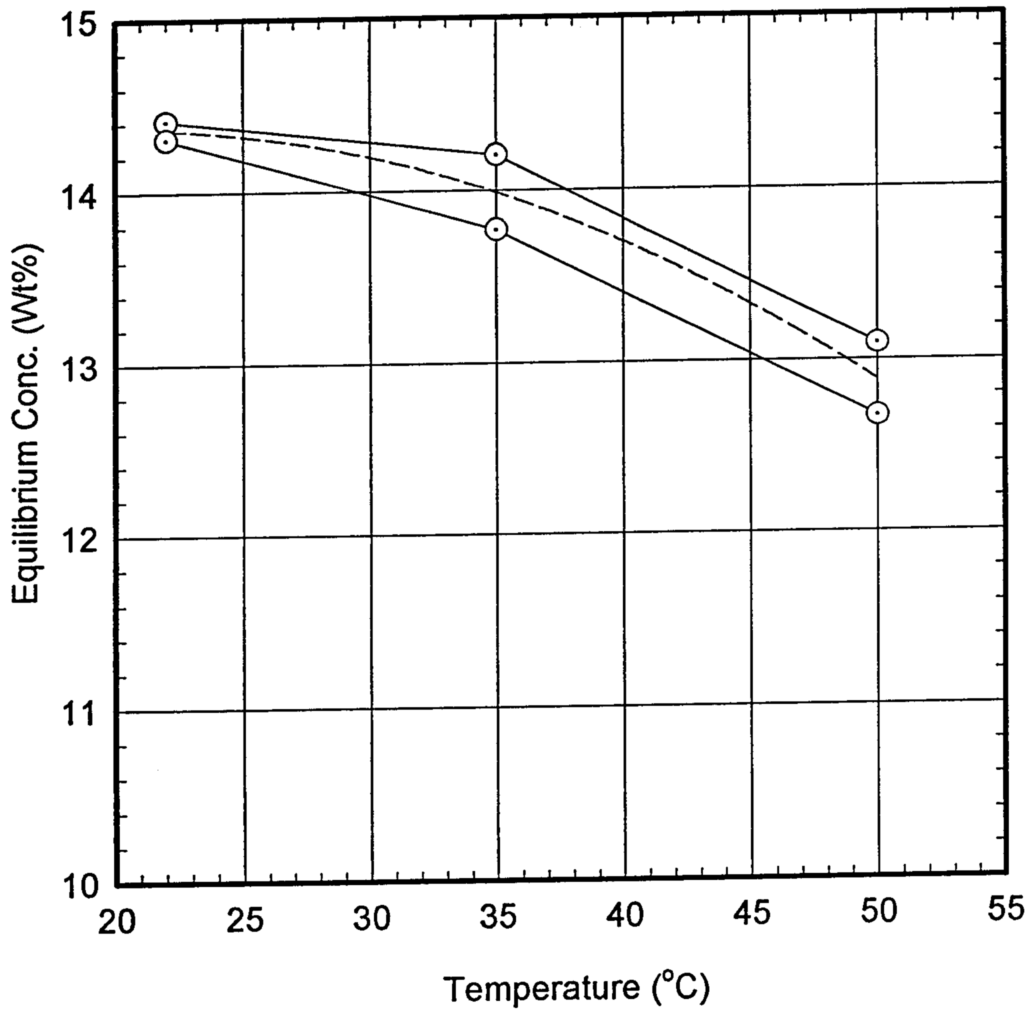

FIGURE 19. MAXIMUM MOISTURE SOLUBILITY IN BALSA WOOD CORE AT 80 PERCENT RH AS A FUNCTION OF TEMPERATURE

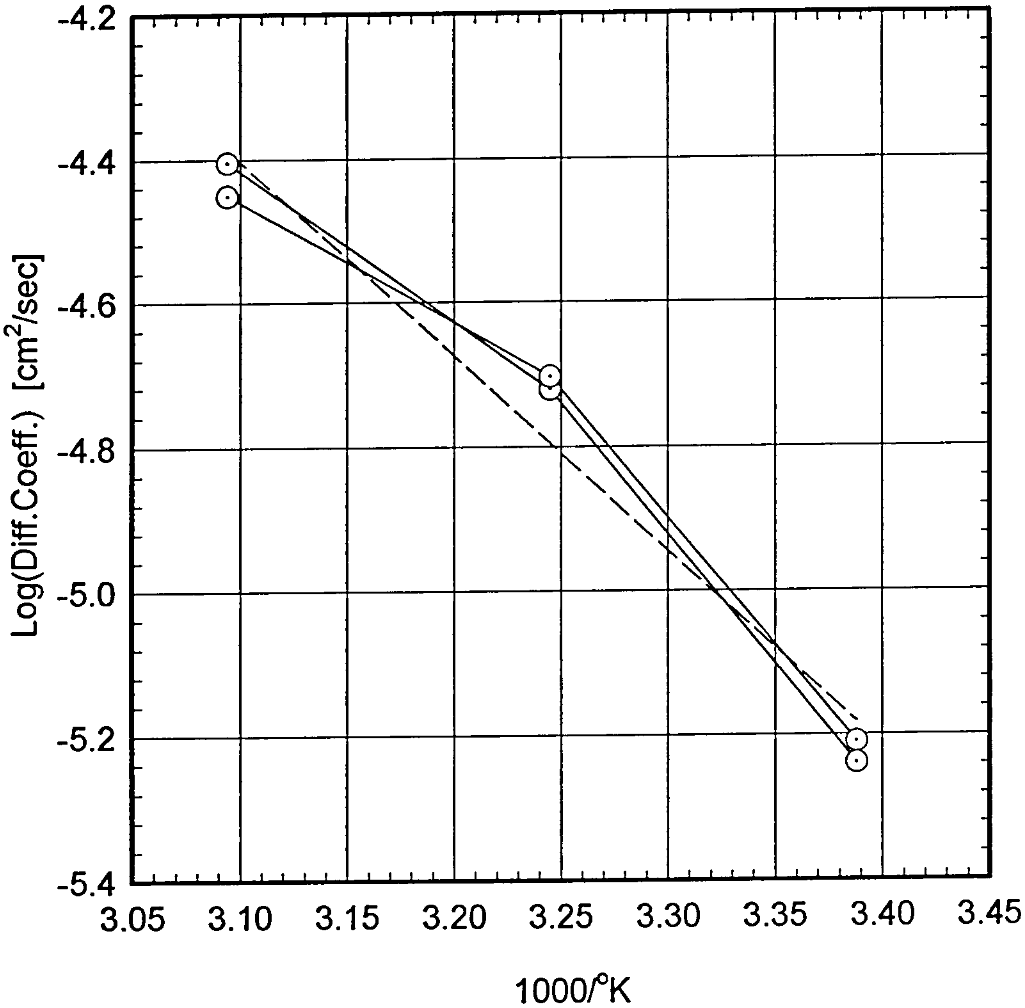

FIGURE 20. ARRHENIUS PLOT OF LOG(D) VERSUS 1/°T AT 80 PERCENT RH FOR BALSA WOOD CORE

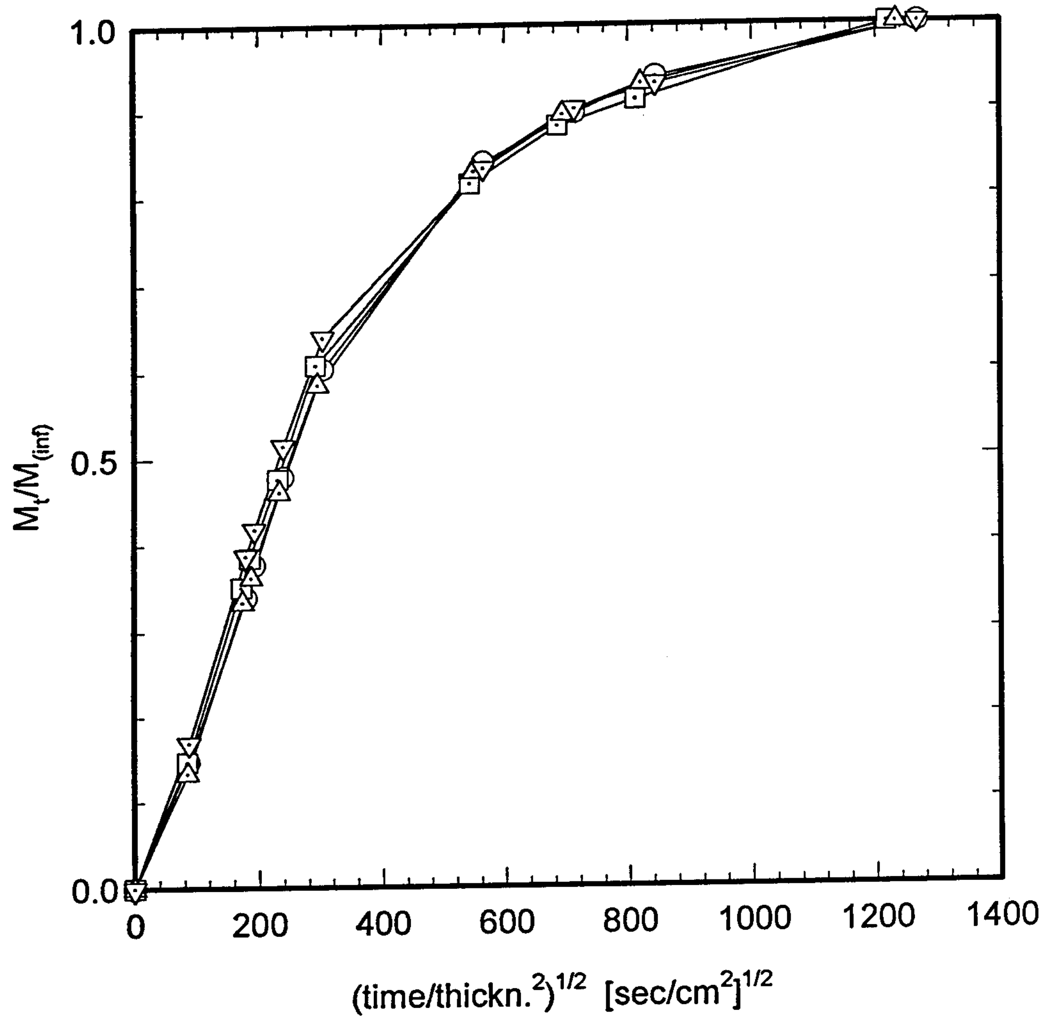

FIGURE 21. MOISTURE SORPTION IN PVC-FOAM CORE AT 22°C AND 80 PERCENT RH

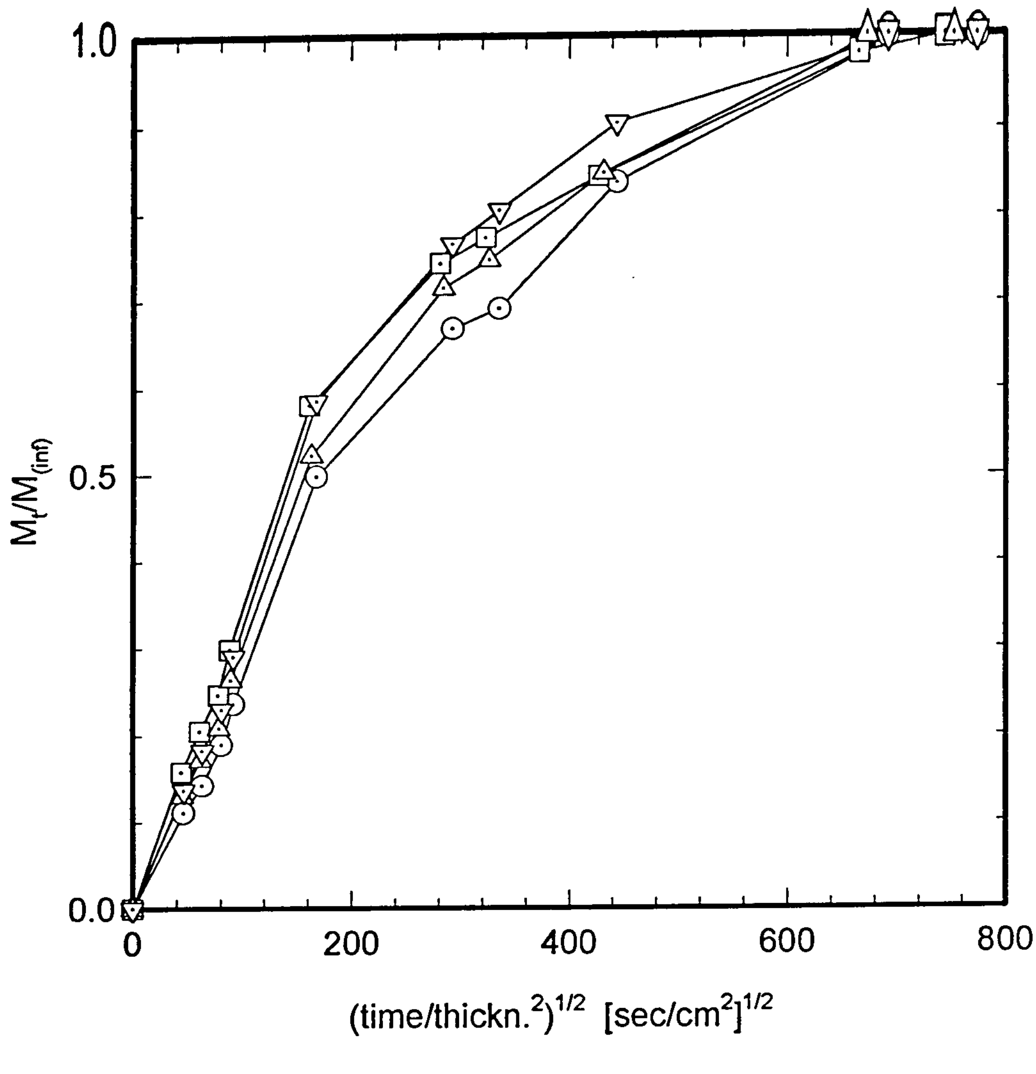

FIGURE 22. MOISTURE SORPTION IN PVC-FOAM CORE AT 50°C AND 80 PERCENT RH

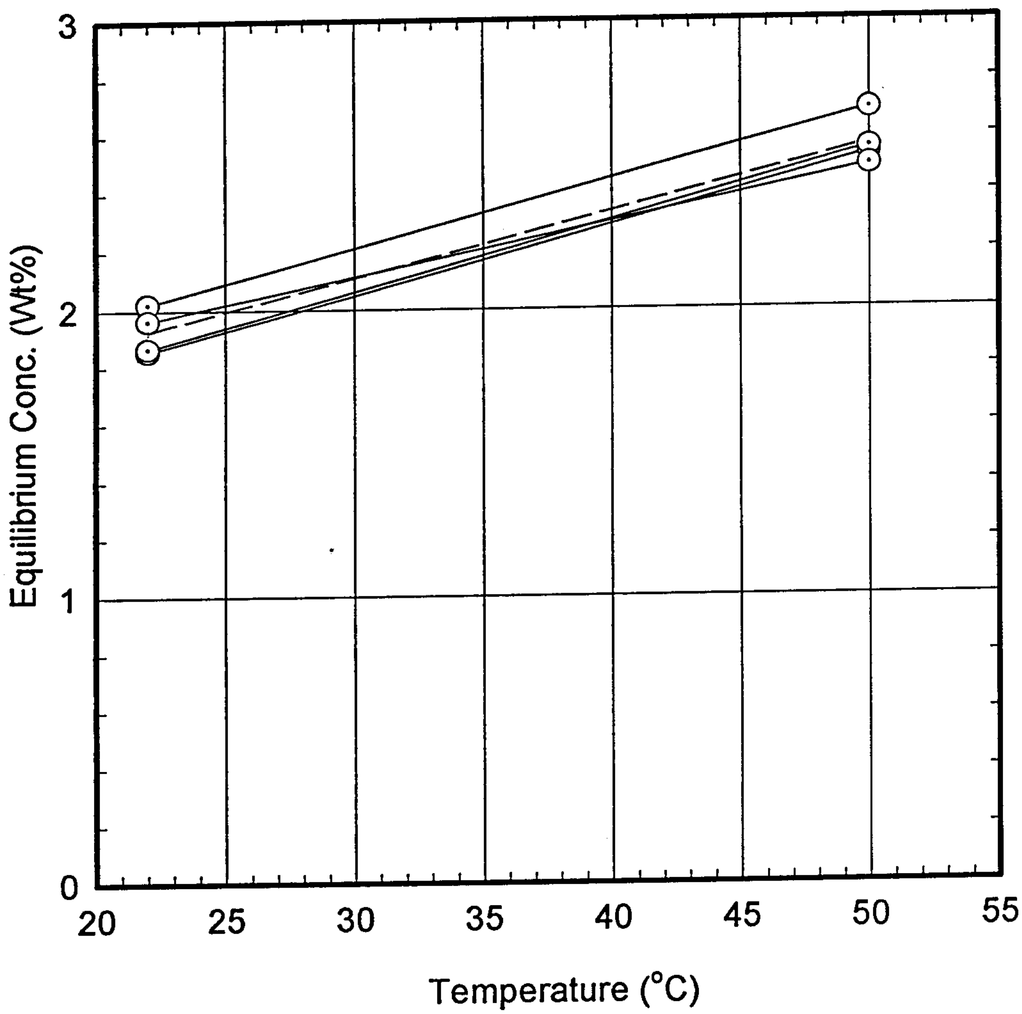

FIGURE 23. MAXIMUM MOISTURE SOLUBILITY IN PVC-FOAM CORE AT 80 PERCENT RH AS A FUNCTION OF TEMPERATURE

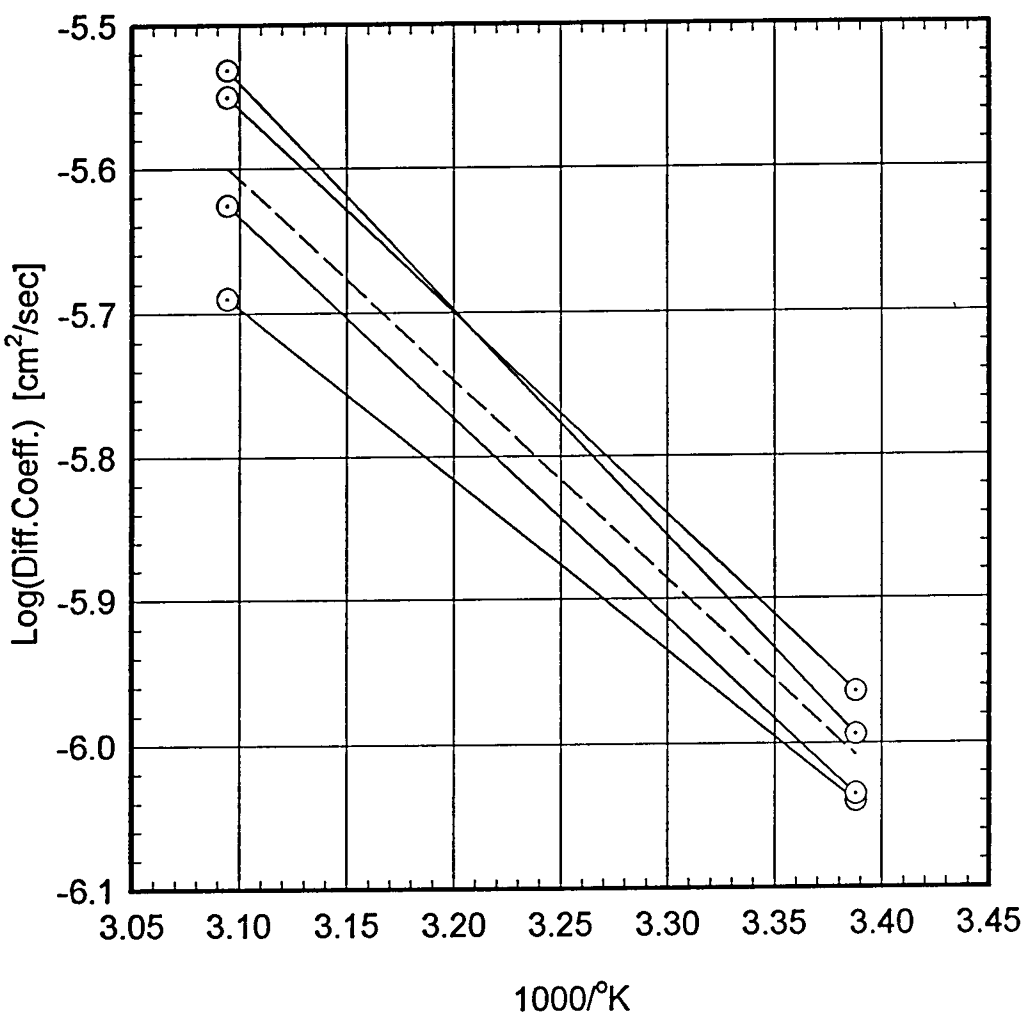

FIGURE 24. ARRHENIUS PLOT OF LOG(D) VERSUS 1/°T AT 80 PERCENT RH FOR PVC-FOAM CORE

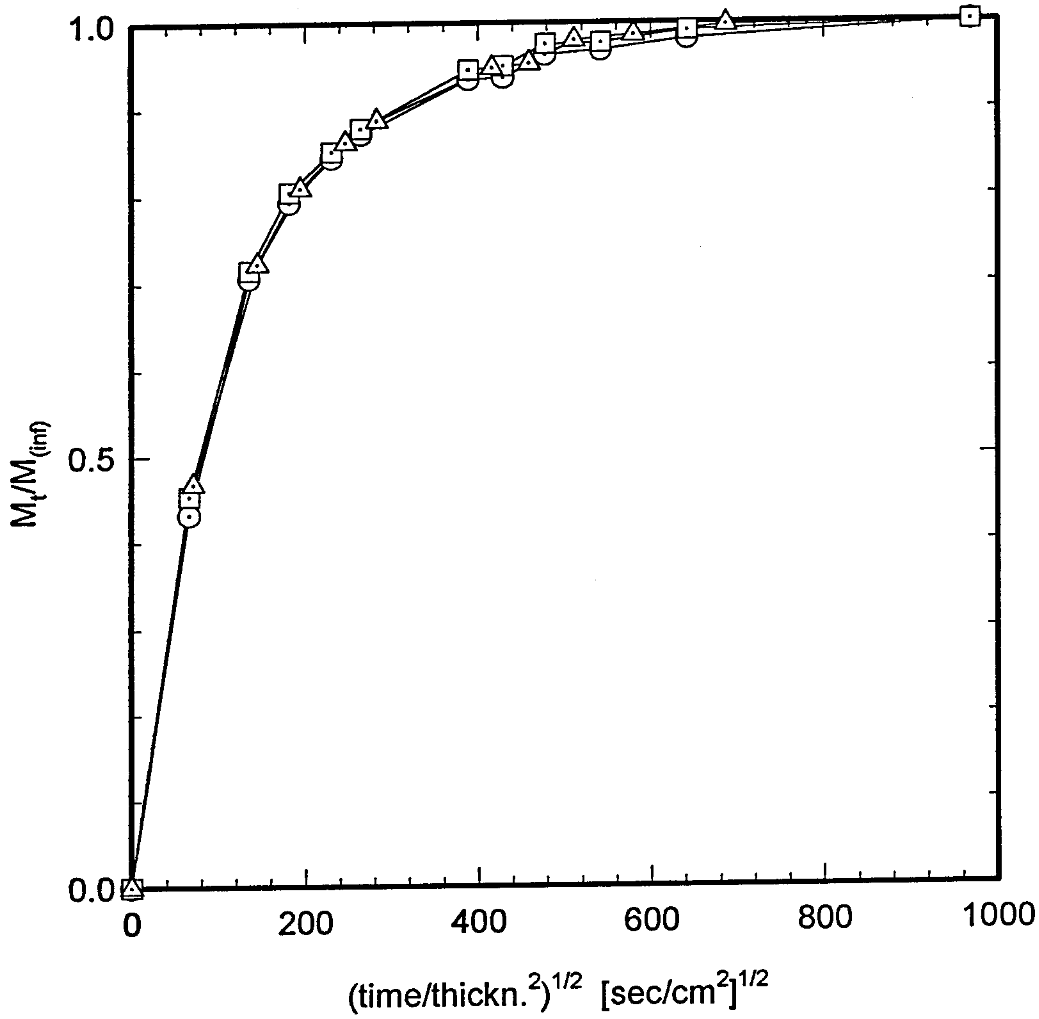

FIGURE 25. MOISTURE SORPTION IN HONEYCOMB CORE AT 22°C AND 80 PERCENT RH

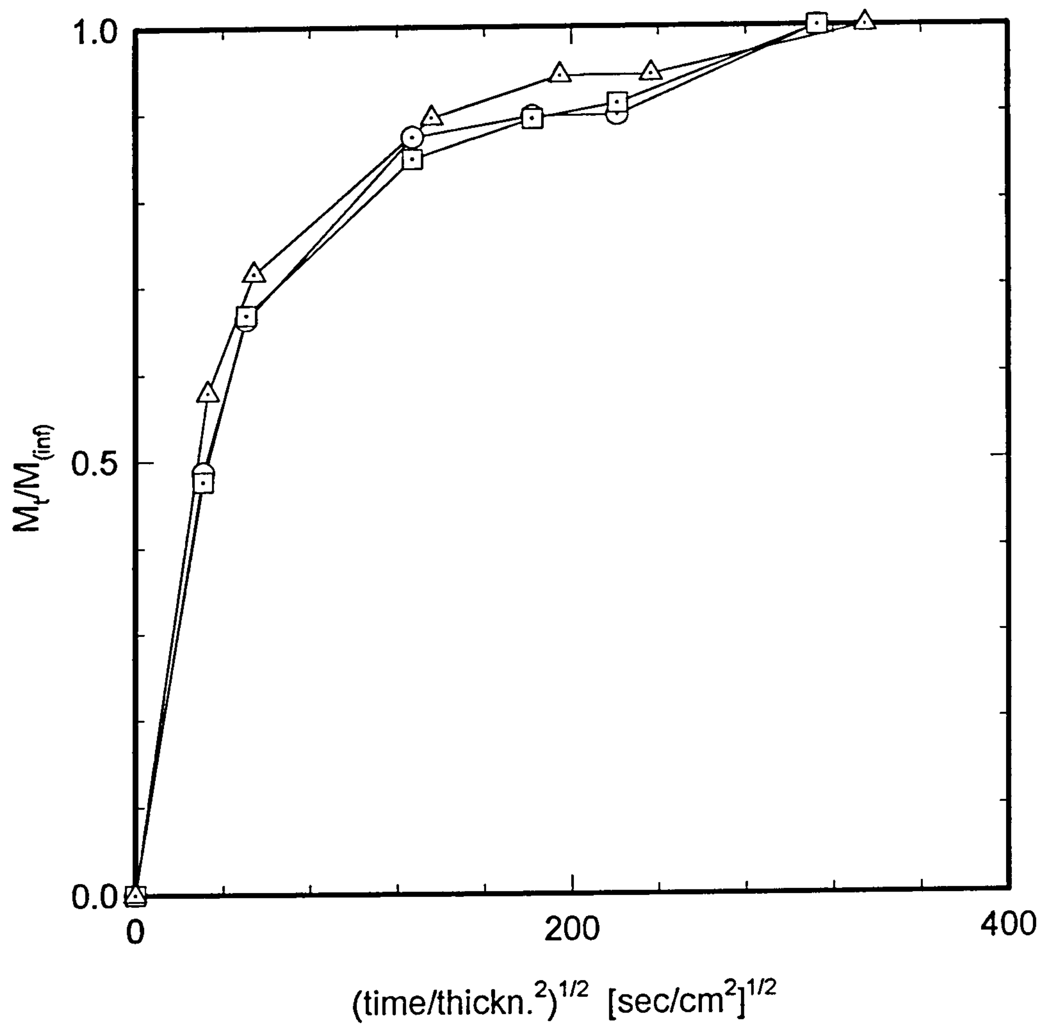

FIGURE 26. MOISTURE SORPTION IN HONEYCOMB CORE AT 50°C AND 80 PERCENT RH

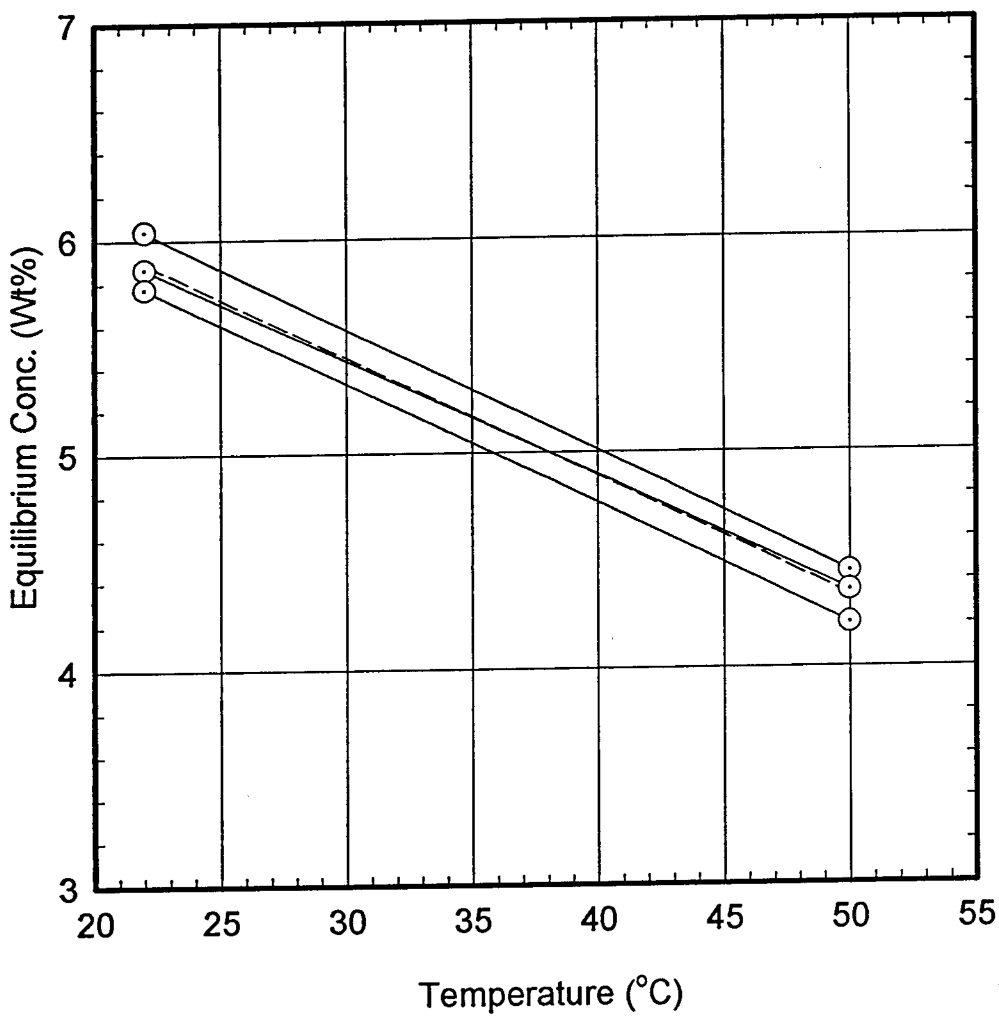

FIGURE 27. MAXIMUM MOISTURE SOLUBILITY IN HONEYCOMB CORE AT 80 PERCENT RH AS A FUNCTION OF TEMPERATURE

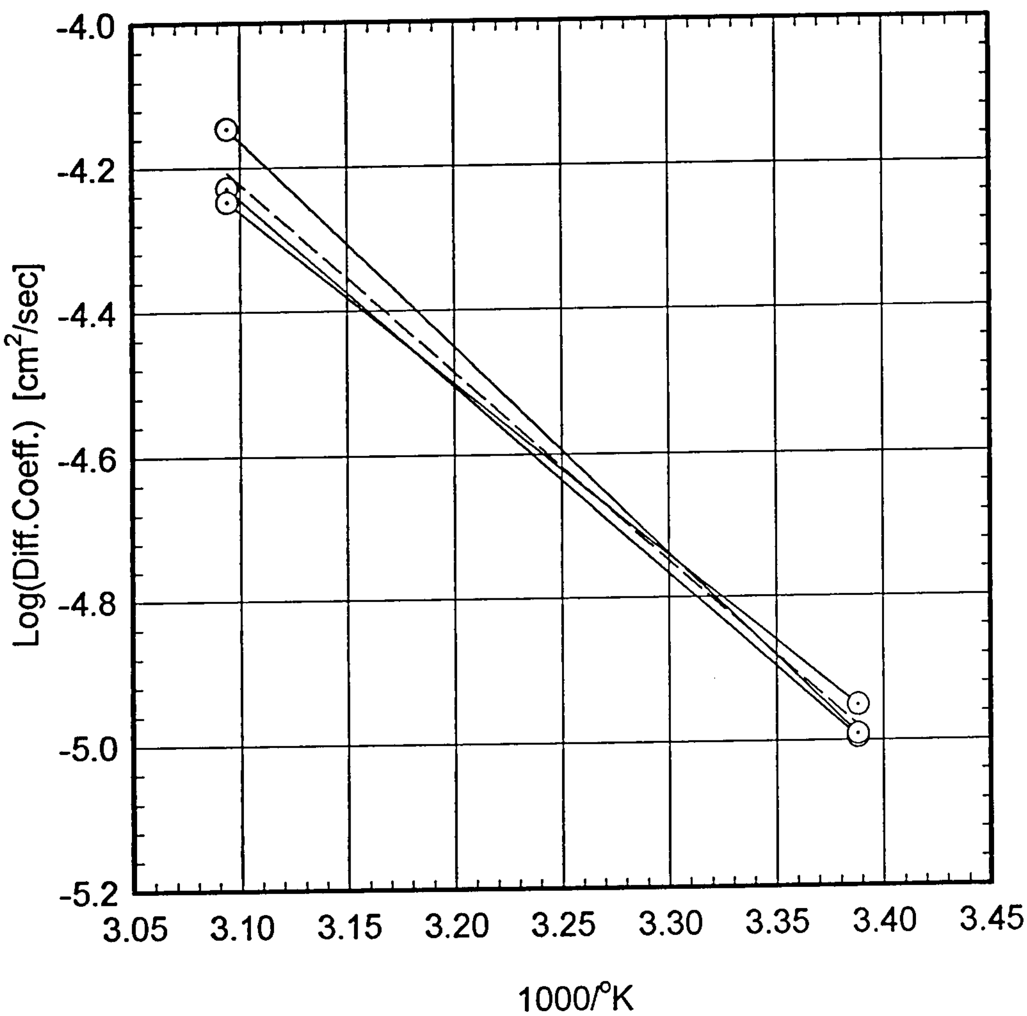

FIGURE 28. ARRHENIUS PLOT OF LOG(D) VERSUS 1/°T AT 80 PERCENT RH FOR HONEYCOMB CORE

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Appendix

EXPERIMENTAL DATA

Page A-3 of the Appendix provides a summary of the experimental data that describe the moisture diffusion behavior of individual constituent materials to be used in AEM/S sandwich constructions. Columns 1 through 3 list the materials, the temperatures of exposure for which the diffusion coefficients and solubilities have been measured, and the experimental average of the corrected diffusion coefficients. From these average diffusion coefficients, measured at different temperatures, the Arrhenius coefficients were obtained via regression analyses. From these coefficients, the diffusion coefficients can be obtained for any temperature of interest, assuming that they are within the valid range of the Arrhenius behavior. Column 4 lists these recalculated values for the respective temperatures. Column 5 lists the experimental averages of the maximum solubilities for the exposure temperatures and column 6 lists the recalculated values after regression analysis. Column 7 lists the average densities obtained from the measured sizes and weights of the samples. The coefficients for calculating the diffusion coefficient for any desired temperature are listed in columns 2 and 3 on the lower part of the page together with the apparent activation energies of diffusion. Also listed are the coefficients for calculating the maximum solubilities between room temperature and 50°C.

The following pages list all the experimental data for each individual material sample at the respective exposure temperatures. These include: sample ID; thickness; length; width; dry weight; weights at various time intervals; the corresponding values for M_t/M_∞ and $(\text{time/thickness}^2)^{1/2}$; the results of the regression analysis for the linear initial slope and intersection of the sorption curve of each sample; the calculated average diffusion coefficient; the corresponding edge correction for the finite lengths and widths of the specimens; and the individual maximum moisture concentration.

Moisture Diffusion and Equilibrium Solubility in AEM/S Materials at 80 Percent RH

Summary of Experimental Data

Material	Temp. Deg. C	Av. Diff. Coeff.	Av.calc.Diff.Coef	Av.Sol.Wt%	Av.Calc.Sol.	Rho (g/ml)
3113 Gl-Epoxy	22	5.90E-10	5.81E-10	0.664	0.664	1.765
	35	1.14E-09	1.17E-09	0.69	0.69	
	50	2.48E-09	2.44E-09	0.802	0.802	
RTM3 Gl-Vinyl	22	2.42E-09	2.56E-09	0.157	0.157	1.925
	35	5.91E-09	5.31E-09	0.164	0.164	
	50	1.10E-08	1.15E-08	0.162	0.161	
G10 Gl-Epoxy	22	4.99E-10	5.05E-10	0.72	0.72	1.827
	35	1.03E-09	1.01E-09	0.725	0.725	
	50	2.08E-09	2.10E-09	0.713	0.713	
Balsa Wood	22	5.97E-06	6.59E-06	14.361	14.361	0.091
	35	1.94E-05	1.60E-05	13.991	13.989	
	50	3.64E-05	4.09E-05	12.884	12.89	
PVC-Foam	22	9.64E-07	9.81E-07	1.927	1.927	0.0745
	50	2.54E-06	2.52E-06	2.564	2.564	
Honeycomb Core	22	1.05E-05	1.05E-05	5.894	5.894	0.062
	50	6.23E-05	6.19E-05	4.332	4.332	

To calculate the Diffusion Coefficient for other temperatures (within the validity of the Arrhenius behavior):
Log(Av.Diff.Coeff.) = b(0) + b(1)*1/(Deg.K)

The Temperature Coefficient (apparent Activation Energy) of Moisture Diffusion is calculated from the slope of Log(Av.D) vs. 1/Deg.K according to the Arrhenius expression: D(T) = D(0)*exp(-Act.En./RT)

To calculate the Equilibrium Moisture Solubilities for temperatures between 20 and 50 Deg.C:
Wt% = a(0) + a(1)*Deg.C + a(2)* Deg.C^2

Coefficients for calculating Log(Av.D)				Coefficients for calculating Solubility		
Material	b(0)	b(1)	Act.En.(kcal/M)	a(0)	a(1)	a(2)
3113 Gl-Epoxy	-2.0331	-2.1262	9.74	0.7696	-9.112E-03	1.954E-04
RTM3 Gl-Vinyl	-1.0614	-2.223	7.74	0.1251	2.018E-03	-2.586E+00
G10 Gl-Epoxy	-2.1558	-2.1079	9.66	0.6819	2.594E-03	-3.927E-05
Balsa Wood	3.9713	-2.7016	12.4	13.7409	6.380E-01	-1.618E+00
PVC-Foam	-1.2893	-1.3929	6.25	1.4259	2.277E-02	0.000E+00
Honeycomb Core	3.9135	-2.6248	12	7.1214	-5.580E-02	0.000E+00

	A	B	C	D	E	F	G	H	I	J	K
1	Moisture Sorption in 3113 Glass Epoxy and Vinyl-Ester Face Sheets at 22 Deg.C and 80% RH										
2											
3	Sample #	3113-a	3113-b	RTM3-1	RTM3-2						
4	Thickness (cm)	0.09218	0.09157	0.082296	0.083058						
5	Length (cm)	4.6	4.6	5.07	5.07						
6	Width (cm)	4.6	4.6	4.83	4.83						
7	Start: 7-11; 730										
8	Dry Weight a,t t=0	3.43593	3.42718	3.88361	3.91377						
9	Wt at t=inf	3.45879	3.44987	3.88976	3.91986						
10											
11	Time out	1410	1410	1410	1410						
12	Min	400	400	400	400						
13	Weight (Grams)	3.43708	3.42869	3.88446	3.91476						
14	Time in										
15	Time out 7-12	1040	1040	1040	1040						
16	Min	1630	1630	1630	1630						
17	Weight	3.43887	3.43082	3.88608	3.91613						
18	Time in										
19	Time out 7-13	820	820	820	820						
20	Min	2930	2930	2930	2930						
21	Weight	3.44032	3.43246	3.88701	3.91717						
22	Time in										
23	Time out 7-14	1355	1355	1355	1355						
24	Min	4705	4705	4705	4705						
25	Weight	3.44188	3.43419	3.88781	3.91805						
26	Time in										
27	Time out 7-15	1435	1435	1435	1435						
28	Min	6185	6185	6185	6185						
29	Weight	3.44324	3.43543	3.88833	3.91849						
30	Time in										
31	Time out 7-20	1350	1350	1350	1350						
32	Min	13345	13345	13345	13345						
33	Weight	3.44739	3.43951	3.88896	3.91918						
34	Time in										
35	Time out 7-22	1430	1430	1430	1430						
36	Min	16265	16265	16265	16265						
37	Weight	3.44881	3.44098	3.88932	3.91941						
38	Time in 7-25										
39	Time out	715	715	715	715						
40	Min	20150	20150	20150	20150						
41	Weight	3.45059	3.44259	3.88961	3.91962						
42	Time in										
43	Time out 7-29	730	730	730	730						
44	Min	25925	25925	25925	25925						
45	Weight	3.45238	3.44431	3.88961	3.91973						
46	Time in										
47	Time out 9-7	1345	1345	1345	1345						
48	Min	36380	36385	36385	36385						
49	Weight	3.45467	3.44633	3.88953	3.91973						
50	Time in										
51	Time out 8-29	1315	1315	1315	1315						
52	Min	70910	70910	70910	70910						
53	Weight	3.45848	3.44969	3.88976	3.91986						
54	Time in										
55	Time out 8-5	645	645								
56	Min	83480	83480								
57	Weight	3.45879	3.44987								
58	Regression Analysis:										
59	b (intersection)	-0.03112	-0.02003	-0.02675	-0.01879						
60	a (x-coeff)	5.27E-05	5.69E-05	0.000111	0.000111						
61											
62	D=x^2*Pi/16	5.45E-10	6.36E-10	2.43E-09	2.41E-09						
63	D(corr. R&M)	5.45E-10	6.36E-10	2.43E-09	2.41E-09						

	A	B	C	D	E	F	G	H	I	J	K
64											
65	35C,80RH Sorb.	0.665322	0.66206	0.158358	0.155604						
66											
67											
68	Mt/M(inf)	0	0	0	0						
69	From: Line 13	0.050306	0.066549	0.138211	0.162562						
70	Line 17	0.128609	0.160423	0.401626	0.387521						
71	Line 21	0.192038	0.232702	0.552846	0.558292						
72	Line 25	0.26028	0.308947	0.682927	0.702791						
73	Line 29	0.319773	0.363596	0.76748	0.775041						
74	Line 33	0.501312	0.543411	0.869919	0.888342						
75	Line 37	0.56343	0.608197	0.928455	0.926108						
76	Line 41	0.641295	0.679154	0.97561	0.960591						
77	Line 45	0.719598	0.754958	0.97561	0.978654						
78	Line 49	0.819773	0.843984	0.962602	0.978654						
79	Line 53	0.986439	0.992067	1	1						
80	Line 57	1	1								
81											
82	(time/th^2)^.5 (sec)	0	0	0	0						
83	From: Line 12	1680.618	1691.813	1882.465	1865.195						
84	Line 16	3392.601	3415.201	3800.062	3765.199						
85	Line 20	4548.547	4578.848	5094.842	5048.1						
86	Line 24	5763.93	5802.327	6456.196	6396.965						
87	Line 28	6608.589	6652.613	7402.301	7334.39						
88	Line 32	9707.295	9771.96	10873.17	10773.42						
89	Line 36	10716.82	10788.21	12003.94	11893.82						
90	Line 40	11928.24	12007.7	13360.86	13238.28						
91	Line 44	13530.02	13620.15	15155.01	15015.98						
92	Line 48	16027.67	16135.54	17953.87	17789.16						
93	Line 52	22376.53	22525.59	25064.01	24834.07						
94	Line 56	24278.96	24440.7								
95											
96											
97											
98											
99											
100											
101											
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124											
125											
126											
127											

	A	B	C	D	E	F	G	H	I	J	K
1	**Moisture Absorption in 3113 Glass Epoxy and Vinyl-Ester Face Sheets at 35 Deg.C and 80% RH**										
2											
3	Sample #	3113-a	3113-b	RTM3-1	RTM3-2						
4	Thickness (cm)	0.092	0.092	0.082	0.083						
5	Length (cm)	4.6	4.6	5.07	5.07						
6	Width (cm)	4.6	4.6	4.83	4.83						
7	Start:										
8	Dry Weight a,t t=0	3.43036	3.42113	3.88305	3.91295						
9	Wt at t=inf	3.45403	3.44474	3.88952	3.91927						
10											
11	Time out	1700	1700	1214	1214						
12	Min	600	600	144	144						
13	Weight (Grams)	3.43391	3.42557	3.88431	3.91406						
14	Time in										
15	Time out	1210	1210	1412	1412						
16	Min	1750	1750	262	262						
17	Weight	3.43645	3.42821	3.88471	3.91449						
18	Time in										
19	Time out	1630	1630	1635	1635						
20	Min	2010	2010	405	405						
21	Weight	3.43675	3.42861	3.88511	3.91492						
22	Time in										
23	Time out	1530	1530	640	640						
24	Min	4830	4830	1250	1250						
25	Weight	3.44058	3.43215	3.88679	3.91655						
26	Time in										
27	Time out	1240	1240	1623	1623						
28	Min	6100	6100	1823	1823						
29	Weight	3.44183	3.43348	3.88736	3.91726						
30	Time in										
31	Time out	1055	1055	640	640						
32	Min	10375	10375	2680	2680						
33	Weight	3.44508	3.43639	3.88801	3.91779						
34	Time in										
35	Time out	1300	1300	1235	1235						
36	Min	23520	23520	4475	4475						
37	Weight	3.44946	3.44024	3.88868	3.91848						
38	Time in										
39	Time out	630	630	635	635						
40	Min	44730	44730	12755	12755						
41	Weight	3.45218	3.44277	3.88947	3.91924						
42	Time in										
43	Time out			1345	1345						
44	Min			20385	20385						
45	Weight			3.88952	3.91927						
46											
47											
48											
49											
50											
51											
52											
53											
54											
55	Regression Analysis:										
56	b (intersection)	-0.00241	0.014546	-0.00341	-0.01075						
57	a (x-coeff)	7.4E-05	7.8E-05	0.000173	0.000174						
58											
59	D=x^2*Pi/16	1.07E-09	1.2E-09	5.9E-09	5.92E-09						
60	D(corr. R&M)	1.07E-09	1.2E-09	5.9E-09	5.92E-09						
61											
62	35C,80RH Sorb.	0.6900	0.6900	0.1666	0.1615						
63											

	A	B	C	D	E	F	G	H	I	J	K
64											
65											
66	Mt/M(inf)	0	0	0	0						
67	From: Line 13	0.149982	0.188089	0.194745	0.175633						
68	Line 17	0.257293	0.299926	0.256569	0.243671						
69	Line 21	0.269968	0.316871	0.318393	0.311709						
70	Line 25	0.43178	0.466834	0.578053	0.56962						
71	Line 29	0.48459	0.523177	0.666151	0.681962						
72	Line 33	0.621898	0.646451	0.766615	0.765823						
73	Line 37	0.806946	0.809547	0.87017	0.875						
74	Line 41	0.921862	0.916724	0.992272	0.995253						
75	Line 45			1	1						
76											
77	(time/th^2)^.5 (sec)	0	0	0	0						
78	From: Line 12	2058.328	2072.04	1129.479	1119.117						
79	Line 16	3515.264	3538.681	1523.518	1509.541						
80	Line 20	3767.359	3792.455	1894.194	1876.816						
81	Line 24	5839.995	5878.899	3327.759	3297.229						
82	Line 28	6563.022	6606.742	4018.743	3981.874						
83	Line 32	8559.196	8616.214	4872.64	4827.937						
84	Line 36	12887.17	12973.02	6296.416	6238.651						
85	Line 40	17772.08	17890.47	10630.09	10532.57						
86	Line 44			13438.55	13315.26						
87											
88											
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	A	B	C	D	E	F	G	H	I	J	K
1	Moisture Absorption in Glass Epoxy and Vinyl-Ester Face Sheets at 50 Deg.C and 80% RH										
2											
3	Sample #	3113-a	3113-b	RTM3-1	RTM3-2						
4	Thickness (cm)	0.09218	0.09157	0.082296	0.083058						
5	Length (cm)	4.6	4.6	5.07	5.07						
6	Width (cm)	4.6	4.6	4.83	4.83						
7	Start:										
8	Dry Weight a,t t=0	3.43353	3.42444	3.88321	3.91314						
9	Wt at t=inf	3.46146	3.45154	3.88937	3.91956						
10											
11	Time out	830	830	830	830						
12	Min	90	90	90	90						
13	Weight (Grams)	3.43528	3.42667	3.88457	3.91464						
14	Time in										
15	Time out	1050	1050	1050	1050						
16	Min	230	230	230	230						
17	Weight	3.43616	3.42769	3.88524	3.91529						
18	Time in										
19	Time out	800	800	800	800						
20	Min	2940	2940	2940	2940						
21	Weight	3.44713	3.43856	3.88857	3.91861						
22	Time in										
23	Time out	700	700	700	700						
24	Min	4320	4320	4320	4320						
25	Weight	3.45032	3.44129	3.88869	3.91884						
26	Time in										
27	Time out	700	700	700	700						
28	Min	8640	8640	8640	8640						
29	Weight	3.45616	3.44706	3.88915	3.91936						
30	Time in										
31	Time out	1500	1500	1500	1500						
32	Min	13440	13440	13440	13440						
33	Weight	3.45833	3.44821	3.88929	3.91937						
34	Time in										
35	Time out	700	700	700	700						
36	Min	23040	23040	23040	23040						
37	Weight	3.46138	3.45106	3.88937	3.91946						
38	Time in										
39	Time out	1300	1300	1300	1300						
40	Min	29160	29160	29160	29160						
41	Weight	3.46146	3.45154	3.88937	3.91956						
42											
43											
44											
45											
46											
47											
48											
49											
50											
51	Regression Analysis:										
52	b (intersection)	-0.02102	-0.01108	0.003578	0.005906						
53	a (x-coeff)	0.00011	0.000115	0.000233	0.00024						
54											
55	D=x^2*Pi/16	2.37E-09	2.6E-09	1.06E-08	1.13E-08						
56	D(corr. R&M)	2.37E-09	2.6E-09	1.06E-08	1.13E-08						
57											
58	50C,80RH Sorb.	0.813449	0.79137	0.158632	0.164063						
59											
60											
61											
62											
63											

	A	B	C	D	E	F	G	H	I	J	K
64											
65	Mt/M(inf)	0	0	0	0						
66	From: Line 13	0.062657	0.082288	0.220779	0.233645						
67	Line 17	0.094164	0.119926	0.329545	0.334891						
68	Line 21	0.486932	0.521033	0.87013	0.852025						
69	Line 25	0.601146	0.621771	0.88961	0.88785						
70	Line 29	0.81024	0.834686	0.964286	0.968847						
71	Line 33	0.887934	0.877122	0.987013	0.970405						
72	Line 37	0.997136	0.982288	1	0.984424						
73	Line 41	1	1	1	1						
74											
75	(time/th^2)^.5 (sec)	0	0	0	0						
76	From: Line 12	797.1869	802.4975	892.9315	884.7395						
77	Line 16	1274.391	1282.881	1427.45	1414.354						
78	Line 20	4556.303	4586.655	5103.529	5056.707						
79	Line 24	5523.073	5559.865	6186.411	6129.655						
80	Line 28	7810.805	7862.837	8748.906	8668.641						
81	Line 32	9741.785	9806.681	10911.8	10811.7						
82	Line 36	12754.99	12839.96	14286.9	14155.83						
83	Line 40	14349.36	14444.95	16072.77	15925.31						
84											
85											
86											
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	A	B	C	D	E	F	G	H	I	J	K
1	Moisture Absorption in G10 E-Glass/Epoxy Cu-facing at 22 Deg.C and 80% RH										
2											
3	Sample #	E-Gl/Epox									
4	Thickness (cm)	0.083									
5	Length (cm)	5.08									
6	Width (cm)	5.08									
7	Start: 7-18; 0645										
8	Dry Weight a,t t=0	3.91388									
9	Wt at t=inf	3.94206									
10											
11	Time out	1400									
12	Min	435									
13	Weight (Grams)	3.91731									
14	Time in										
15	Time out 7-19	1430									
16	Min	1905									
17	Weight	3.92014									
18	Time in										
19	Time out 7-20	1355									
20	Min	3310									
21	Weight	3.92186									
22	Time in										
23	Time out 7-21	1500									
24	Min	4815									
25	Weight	3.92344									
26	Time in										
27	Time out 7-22	1430									
28	Min	6225									
29	Weight	3.92466									
30	Time in										
31	Time out 7-25	720									
32	Min	10115									
33	Weight	3.92741									
34	Time in										
35	Time out 7-29	750									
36	Min	15905									
37	Weight	3.93061									
38	Time in										
39	Time out 8-5	1350									
40	Min	26345									
41	Weight	3.93395									
42	Time in										
43	Time out 8-29	1330									
44	Min	60920									
45	Weight	3.93837									
46											
47											
48											
49											
50											
51											
52											
53											
54	Regression Analysis: using the first 7 points (zero included)										
55	b (intersection)	0.01217									
56	a (x-coeff)	5.04E-05									
57											
58	D=x^2*Pi/16	4.98E-10									
59	D(corr. R&M)	4.99E-10									
60											
61	22C,80RH Sorb.	0.72									
62											
63											

	A	B	C	D	E	F	G	H	I	J	K
64											
65	Mt/M(inf)	0									
66	From: Line 13	0.121718									
67	Line 17	0.222144									
68	Line 21	0.28318									
69	Line 25	0.339248									
70	Line 29	0.382542									
71	Line 33	0.480129									
72	Line 37	0.593685									
73	Line 41	0.712209									
74	Line 45	0.869058									
75											
76	(time/th^2)^.5 (sec)	0									
77	From: Line 12	1946.445									
78	Line 16	4073.287									
79	Line 20	5369.224									
80	Line 24	6475.834									
81	Line 28	7363.21									
82	Line 32	9385.998									
83	Line 36	11769.67									
84	Line 40	15147.7									
85	Line 44	23034.43									
86											
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89											
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	A	B
1	Moisture Absorption in G10 E-Glass/Epoxy Cu-facing at 35 Deg.C and 80% RH	
2		
3	Sample #	E-Gl/Epox
4	Thickness (cm)	0.083
5	Length (cm)	5.08
6	Width (cm)	5.08
7	Start:	
8	Dry Weight a,t t=0	3.90959
9	Wt at t=inf	3.93792
10		
11	Time out	1523
12	Min	473
13	Weight (Grams)	3.91407
14	Time in	1525
15	Time out	700
16	Min	1408
17	Weight	3.91674
18	Time in	703
19	Time out	1000
20	Min	2920
21	Weight	3.92002
22	Time in	
23	Time out	655
24	Min	7055
25	Weight	3.92555
26	Time in	
27	Time out	650
28	Min	11370
29	Weight	3.92901
30	Time in	650
31	Time out	
32	Min	17130
33	Weight	3.93105
34	Time in	
35	Time out	750
36	Min	20070
37	Weight	3.93163
38	Time in	
39	Time out	1055
40	Min	23075
41	Weight	3.93201
42	Time in	
43	Time out	730
44	Min	27190
45	Weight	3.93279
46	Time in	
47	Time out	1610
48	Min	33470
49	Weight	3.93339
50	Time in	
51	Time out	725
52	Min	47345
53	Weight	3.93426
54	Time in	
55	Time out	800
56	Min	53140
57	Weight	3.93448
58	Time in	
59	Time out	850
60	Min	77670
61	Weight	3.93574
62	Time in	
63	Time out	715
64	Min	87655

	A	B	C	D	E	F	G	H	I	J	K
65	Weight	3.93611									
66	Time in										
67	Time out	1415									
68	Min	103915									
69	Weight	3.93664									
70	Time in										
71	Time out	1300									
72	Min	171535									
73	Weight	3.93792									
74											
75											
76	Regression Analysis:	using the first 7 points (zero included)									
77	b (intersection)	0.003375									
78	a (x-coeff)	7.24E-05									
79											
80	D=x^2*Pi/16	1.03E-09									
81	D(corr. R&M)	1.03E-09									
82											
83	35C,80RH Sorb.	0.724628									
84											
85											
86	Mt/M(inf)	0									
87	From: Line 13	0.158136									
88	Line 17	0.252383									
89	Line 21	0.368161									
90	Line 25	0.56336									
91	Line 29	0.685492									
92	Line 33	0.757501									
93	Line 37	0.777974									
94	Line 41	0.791387									
95	Line 45	0.81892									
96	Line 49	0.840099									
97	Line 53	0.870808									
98	Line 57	0.878574									
99	Line 61	0.92305									
100	Line 65	0.93611									
101	Line 69	0.954818									
102	Line 73	1									
103											
104	(time/th^2)^.5 (sec)	0									
105	From: Line 12	2029.682									
106	Line 16	3501.861									
107	Line 20	5043									
108	Line 24	7838.736									
109	Line 28	9951.253									
110	Line 32	12214.51									
111	Line 36	13221.21									
112	Line 40	14176.48									
113	Line 44	15388.71									
114	Line 48	17073.61									
115	Line 52	20306.48									
116	Line 56	21513.36									
117	Line 60	26009.03									
118	Line 64	27630.32									
119	Line 68	30084.07									
120	Line 72	38652.17									

	A	B	C	D	E	F	G	H	I	J	K
1	**Moisture Absorption in G10 E-Glass/Epoxy Cu-facing at 50 Deg.C and 80% RH**										
2											
3	Sample #	Gl.Epox									
4	Thickness (cm)	0.083									
5	Length (cm)	5.08									
6	Width (cm)	5.08									
7	Start:										
8	Dry Weight a,t t=0	3.91184									
9	Wt at t=inf	3.93975									
10											
11	Time out	830									
12	Min	90									
13	Weight (Grams)	3.91447									
14	Time in										
15	Time out	1050									
16	Min	230									
17	Weight	3.91569									
18	Time in										
19	Time out	700									
20	Min	1440									
21	Weight	3.92222									
22	Time in										
23	Time out	800									
24	Min	2940									
25	Weight	3.92625									
26	Time in										
27	Time out	700									
28	Min	4320									
29	Weight	3.92921									
30	Time in										
31	Time out	700									
32	Min	8640									
33	Weight	3.93357									
34	Time in										
35	Time out	700									
36	Min	23040									
37	Weight	3.93816									
38	Time in										
39	Time out	1300									
40	Min	29160									
41	Weight	3.93938									
42	Time in										
43	Time out	1330									
44	Min	43590									
45	Weight	3.93975									
46											
47											
48											
49											
50											
51											
52	Regression Analysis:	using the first 5 points									
53	b (intersection)	-0.00021									
54	a (x-coeff)	0.000103									
55											
56	D=x^2*Pi/16	2.08E-09									
57	D(corr. R&M)	2.08E-09									
58											
59	505C,80RH Sorb.	0.713475									
60											
61											
62											
63											

	A	B	C	D	E	F	G	H	I	J	K
64											
65											
66	Mt/M(inf)	0									
67	From: Line 13	0.094231									
68	Line 17	0.137943									
69	Line 21	0.37191									
70	Line 25	0.516302									
71	Line 29	0.622358									
72	Line 33	0.778574									
73	Line 37	0.943031									
74	Line 41	0.986743									
75	Line 45	1									
76											
77	(time/th^2)^.5 (sec)	0									
78	From: Line 12	885.3577									
79	Line 16	1415.342									
80	Line 20	3541.431									
81	Line 24	5060.241									
82	Line 28	6133.938									
83	Line 32	8674.699									
84	Line 36	14165.72									
85	Line 40	15936.44									
86	Line 44	19484.58									
87											
88											
89											
90											
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92											
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	A	B	C	D	E	F	G	H	I	J	K
1	Moisture Absorption in in Balsa Wood at 22 Deg.C and 80% RH										
2											
3	Sample #	Balsa 1	Balsa 2								
4	Thickness (cm)	2.3	2.32								
5	Length (cm)	4.95	4.95								
6	Width (cm)	4.95	4.95								
7	Start: 7-11; 0730										
8	Dry Weight a,t t=0	5.1876	5.1098								
9	Wt at t=inf	5.9353	5.8409								
10											
11	Time out	1410	1410								
12	Min	400	400								
13	Weight (Grams)	5.4341	5.3565								
14	Time in										
15	Time out	1030	1030								
16	Min	1620	1620								
17	Weight	5.6749	5.5682								
18	Time in										
19	Time out 7-13	805	805								
20	Min	2915	2915								
21	Weight	5.7668	5.6685								
22	Time in										
23	Time out 7-14	1340	1340								
24	Min	4690	4690								
25	Weight	5.82868	5.7332								
26	Time in										
27	Time out 7-15	1425	1425								
28	Min	6175	6175								
29	Weight	5.8443	5.7487								
30	Time in										
31	Time out 7-20	1345	1345								
32	Min	13335	13335								
33	Weight	5.8875	5.8017								
34	Time in										
35	Time out 7-22	1420	1420								
36	Min	16250	16250								
37	Weight	5.8954	5.8043								
38	Time in										
39	Time out 7-25	705	705								
40	Min	20135	20135								
41	Weight	5.907	5.8155								
42	Time in										
43	Time out 7-29	735	735								
44	Min	25925	25925								
45	Weight	5.9147	5.8233								
46	Time in										
47	Time out 8-5	1340	1340								
48	Min	36370	36370								
49	Weight	5.921	5.8302								
50	Time in										
51	Time out 8-29	1315	1315								
52	Min	70905	70905								
53	Weight	5.9353	5.8409								
54											
55											
56	Regression Analysis:	using the first 2 points (zero included)									
57	b (intersection)	0.033942	0.02535								
58	a (x-coeff)	0.004895	0.005053								
59											
60	D=x^2*Pi/16	4.7E-06	5.01E-06								
61	D(corr. R&M)	5.77E-06	6.17E-06								
62											
63	22C,80RH Sorb.	14.41322	14.3078								

	A	B	C	D	E	F	G	H	I	J	K
64											
65											
66	Mt/M(inf)	0	0								
67	From: Line 13	0.445496	0.433313								
68	Line 17	0.509688	0.492556								
69	Line 21	0.581867	0.608871								
70	Line 25	0.649756	0.664392								
71	Line 29	0.929005	0.948511								
72	Line 33	1	0.979373								
73	Line 37	1	1								
74	Line 41	1	1								
75											
76	(time/th^2)^.5 (sec)	0	0								
77	From: Line 12	34.83691	34.5366								
78	Line 16	47.62805	47.21746								
79	Line 20	61.17934	60.65193								
80	Line 24	69.59239	68.99245								
81	Line 28	180.1071	178.5544								
82	Line 32	222.6325	220.7132								
83	Line 36	255.488	253.2855								
84	Line 40	337.8739	334.9612								
85											
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	A	B	C
1	**Moisture Sorption of Moisture in Balsa Wood at 35 Deg.C and 80 RH**		
2			
3	Sample #	Balsa 1	Balsa 2
4	Thickness (cm)	2.30	2.32
5	Length (cm)	4.95	4.95
6	Width (cm)	4.95	4.95
7	Start:		
8	Dry Weight a,t t=0	5.19719	5.11678
9	Wt at t=inf	5.9354	5.8217
10			
11	Time out	1208	1208
12	Min	138	138
13	Weight (Grams)	5.44989	5.37172
14	Time in		
15	Time out	1405	1405
16	Min	255	255
17	Weight	5.55114	5.45593
18	Time in		
19	Time out	1631	1631
20	Min	401	401
21	Weight	5.6225	5.52134
22	Time in		
23	Time out	1620	1620
24	Min	1830	1830
25	Weight	5.8419	5.7279
26	Time in		
27	Time out	640	640
28	Min	2690	2690
29	Weight	5.8563	5.7466
30	Time in		
31	Time out	1235	1235
32	Min	4485	4485
33	Weight	5.9044	5.7695
34	Time in		
35	Time out	630	630
36	Min	12770	12770
37	Weight	5.9221	5.7938
38	Time in		
39	Time out	1345	1345
40	Min	20405	20405
41	Weight	5.9354	5.8217
42			
43			
44			
45			
46			
47			
48			
49			
50			
51			
52			
53	Regression Analysis: using the first 3 points		
54	b (intersection)	-0.00171	0.001267
55	a (x-coeff)	0.008871	0.00906
56			
57	D=x^2*Pi/16	1.54E-05	1.61E-05
58	D(corr. R&M)	1.9E-05	1.98E-05
59			
60	35C,80RH Sorb.	14.20402	13.77663
61			
62			
63			

	A	B	C	D	E	F	G	H	I	J	K
64											
65											
66	Mt/M(inf)	0	0								
67	From: Line 13	0.342315	0.361658								
68	Line 17	0.479471	0.481118								
69	Line 21	0.576137	0.573909								
70	Line 25	0.873342	0.866935								
71	Line 29	0.892849	0.893463								
72	Line 33	0.958007	0.925949								
73	Line 37	0.981983	0.960421								
74	Line 41	1	1								
75											
76	(time/th^2)^.5 (sec)	0	0								
77	From: Line 12	39.51098	39.24694								
78	Line 16	53.70916	53.35024								
79	Line 20	67.352	66.9019								
80	Line 24	143.8811	142.9196								
81	Line 28	174.4434	173.2776								
82	Line 32	225.2473	223.742								
83	Line 36	380.0789	377.5389								
84	Line 40	480.4482	477.2375								
85	Line 44										
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	A	B	C	D	E	F	G	H	I	J	K
1	Moisture Absorption in in Balsa Wood at 50 Deg.C and 80% RH										
2											
3	Sample #	Balsa 1	Balsa 2								
4	Thickness (cm)	2.3	2.32								
5	Length (cm)	4.95	4.95								
6	Width (cm)	4.95	4.95								
7	Start:										
8	Dry Weight a,t t=0	5.1629	5.0885								
9	Wt at t=inf	5.839	5.7333								
10											
11	Time out	847	847								
12	Min	107	107								
13	Weight (Grams)	5.4641	5.3679								
14	Time in										
15	Time out	1020	1020								
16	Min	200	200								
17	Weight	5.5075	5.4061								
18	Time in										
19	Time out	1230	1230								
20	Min	330	330								
21	Weight	5.5563	5.4811								
22	Time in										
23	Time out	1407	1407								
24	Min	427	427								
25	Weight	5.6022	5.5169								
26	Time in										
27	Time out	640	640								
28	Min	2860	2860								
29	Weight	5.791	5.7001								
30	Time in										
31	Time out	750	750								
32	Min	4370	4370								
33	Weight	5.839	5.72								
34	Time in										
35	Time out	655	655								
36	Min	5755	5755								
37	Weight	5.839	5.7333								
38	Time in										
39	Time out	645	645								
40	Min	10065	10065								
41	Weight	5.839	5.7333								
42											
43											
44											
45											
46											
47											
48											
49											
50											
51	Regression Analysis:										
52	b (intersection)	0	0								
53	a (x-coeff)	0.012438	0.012097								
54											
55	D=x^2*Pi/16	3.04E-05	2.87E-05								
56	D(corr. R&M)	3.73E-05	3.54E-05								
57											
58	50C,80RH Sorb.	13.09535	12.67171								
59											
60											
61											
62											
63											

	A	B	C	D	E	F	G	H	I	J	K
64											
65											
66	Mt/M(inf)	0	0								
67	From: Line 13	0.445496	0.433313								
68	Line 17	0.509688	0.492556								
69	Line 21	0.581867	0.608871								
70	Line 25	0.649756	0.664392								
71	Line 29	0.929005	0.948511								
72	Line 33	1	0.979373								
73	Line 37	1	1								
74	Line 41	1	1								
75											
76	(time/th^2)^.5 (sec)	0	0								
77	From: Line 12	34.83691	34.5366								
78	Line 16	47.62805	47.21746								
79	Line 20	61.17934	60.65193								
80	Line 24	69.59239	68.99245								
81	Line 28	180.1071	178.5544								
82	Line 32	222.6325	220.7132								
83	Line 36	255.488	253.2855								
84	Line 40	337.8739	334.9612								
85											
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	A	B	C	D	E	F	G	H	I	J	K
1	Moisture Absorption in PVC-Foams at 22 Deg.C and 80% RH										
2											
3	Sample #	1A	1B	2A	2B						
4	Thickness (cm)	1.75	1.82	1.8	1.75						
5	Length (cm)	7.3	7.25	7.15	7.1						
6		3.4	3.4	3.35	3.35						
7	Start: 7-11; 730										
8	Dry Weight a,t t=0	3.6172	2.8884	3.5797	2.8						
9	Wt at t=inf	3.6843	2.9468	3.6465	2.855						
10											
11	Time out	1400	1400	1400	1400						
12	Min	390	390	390	390						
13	Weight (Grams)	3.6271	2.89695	3.5886	2.8093						
14	Time in										
15	Time out 7-12	1035	1035	1035	1035						
16	Min	1625	1625	1625	1625						
17	Weight	3.64	2.9089	3.602	2.8213						
18	Time in										
19	Time out	1500	1500	1500	1500						
20	Min	1890	1890	1890	1890						
21	Weight	3.6425	2.9109	3.6039	2.823						
22	Time in										
23	Time out 7-13	815	815	815	815						
24	Min	2925	2925	2925	2925						
25	Weight	3.6493	2.9162	3.6105	2.8283						
26	Time in										
27	Time out 7-14	1345	1345	1345	1345						
28	Min	4695	4695	4695	4695						
29	Weight	3.6577	2.9239	3.6188	2.8352						
30	Time in										
31	Time out 7-22	1430	1430	1430	1430						
32	Min	16265	16265	16265	16265						
33	Weight	3.67355	2.936	3.6351	2.8458						
34	Time in										
35	Time out 7-29	740	740	740	740						
36	Min	25935	25935	25935	25935						
37	Weight	3.6774	2.9399	3.6395	2.8496						
38	Time in										
39	Time out 8-5	1345	1345	1345	1345						
40	Min	36380	36380	36380	36380						
41	Weight	3.6802	2.9417	3.6419	2.8512						
42	Time in										
43	Time out 9-7	645	645	645	645						
44	Min	82040	82040	82040	82040						
45	Weight	3.6843	2.9468	3.6465	2.855						
46											
47											
48											
49											
50											
51	Regression Analysis: using the first 5 points (zero included)										
52	b (intersection)	-0.01168	-0.01115	-0.01451	-0.00733						
53	a (x-coeff)	0.002008	0.002109	0.002009	0.002187						
54											
55	D=x^2*Pi/16	7.92E-07	8.73E-07	7.93E-07	9.39E-07						
56	D(corr. R&M)	9.12E-07	1.01E-06	9.22E-07	1.09E-06						
57											
58	22C,80RH Sorb.	1.855026	2.021881	1.866078	1.964286						
59											
60											
61											
62											
63											

	A	B	C	D	E	F	G	H	I	J	K
64											
65											
66	Mt/M(inf)	0	0	0	0						
67	From: Line 13	0.147541	0.146404	0.133234	0.169091						
68	Line 17	0.339791	0.351027	0.333832	0.387273						
69	Line 21	0.377049	0.385274	0.362275	0.418182						
70	Line 25	0.47839	0.476027	0.461078	0.514545						
71	Line 29	0.603577	0.607877	0.585329	0.64						
72	Line 33	0.839791	0.815068	0.829341	0.832727						
73	Line 37	0.897168	0.881849	0.89521	0.901818						
74	Line 41	0.938897	0.912671	0.931138	0.930909						
75	Line 45	1	1	1	1						
76											
77											
78	(time/th^2)^.5 (sec)	0	0	0	0						
79	From: Line 12	87.41176	84.04977	84.98366	87.41176						
80	Line 16	178.4285	171.5659	173.4722	178.4285						
81	Line 20	192.4281	185.027	187.0829	192.4281						
82	Line 24	239.387	230.1798	232.7373	239.387						
83	Line 28	303.2881	291.6232	294.8634	303.2881						
84	Line 32	564.5009	542.7893	548.8203	564.5009						
85	Line 36	712.8214	685.4052	693.0208	712.8214						
86	Line 40	844.2458	811.7748	820.7946	844.2458						
87	Line 44	1267.799	1219.037	1232.582	1267.799						
88											
89											
90											
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	A	B	C	D	E	F	G	H	I	J	K
1	Moisture Absorption in PVC-Foams at 50 Deg.C and 80% RH										
2											
3	Sample #	1A	1B	2A	2B						
4	Thickness (cm)	1.75	1.82	1.8	1.75						
5	Length (cm)	7.3	7.25	7.15	7.1						
6	Width (cm)	3.4	3.4	3.35	3.35						
7	Start:										
8	Dry Weight a,t t=0	3.61705	2.89521	3.58301	2.80186						
9	Wt at t=inf	3.7086	2.973	3.6744	2.8716						
10											
11	Time out	850	850	850	850						
12	Min	110	110	110	110						
13	Weight (Grams)	3.6272	2.9075	3.5949	2.8114						
14	Time in										
15	Time out	1025	1025	1025	1025						
16	Min	205	205	205	205						
17	Weight	3.6301	2.9112	3.5987	2.8146						
18	Time in										
19	Time out	1233	1233	1233	1233						
20	Min	333	333	333	333						
21	Weight	3.6344	2.9144	3.6021	2.8179						
22	Time in										
23	Time out	1410	1410	1410	1410						
24	Min	430	430	430	430						
25	Weight	3.6387	2.9184	3.6071	2.8221						
26	Time in										
27	Time out	650	650	650	650						
28	Min	1430	1430	1430	1430						
29	Weight	3.6627	2.9404	3.6308	2.8427						
30	Time in										
31	Time out	750	750	750	750						
32	Min	4370	4370	4370	4370						
33	Weight	3.6783	2.9531	3.6484	2.8553						
34	Time in										
35	Time out	650	650	650	650						
36	Min	5750	5750	5750	5750						
37	Weight	3.6804	2.9554	3.6514	2.858						
38	Time in										
39	Time out	645	645	645	645						
40	Min	10060	10060	10060	10060						
41	Weight	3.6937	2.9609	3.6605	2.865						
42	Time in										
43	Time out	700	700	700	700						
44	Min	24475	24475	24475	24475						
45	Weight	3.7086	2.9718	3.6744	2.8716						
46	Time in										
47	Time out	1300	1300	1300	1300						
48	Min	30595	30595	30595	30595						
49	Weight	3.7086	2.973	3.6744	2.8716						
50											
51											
52											
53											
54											
55	Regression Analysis: using the first 6 points (zero included)										
56	b (intersection)	-0.0289	-0.01056	-0.01841	-0.02643						
57	a (x-coeff)	0.003005	0.00359	0.003219	0.003522						
58											
59	D=x^2*Pi/16	1.77E-06	2.53E-06	2.03E-06	2.44E-06						
60	D(corr. R&M)	2.04E-06	2.94E-06	2.37E-06	2.82E-06						
61											
62	50C,80RH Sorb.	2.531068	2.686852	2.550649	2.489061						
63											

	A	B	C	D	E	F	G	H	I	J	K
64											
65											
66	Mt/M(inf)	0	0	0	0						
67	From: Line 13	0.110868	0.157989	0.130102	0.136794						
68	Line 17	0.142545	0.205553	0.171682	0.182679						
69	Line 21	0.189514	0.24669	0.208885	0.229997						
70	Line 25	0.236483	0.29811	0.263596	0.290221						
71	Line 29	0.498635	0.580923	0.522924	0.585604						
72	Line 33	0.669033	0.744183	0.715505	0.766275						
73	Line 37	0.691972	0.77375	0.748331	0.80499						
74	Line 41	0.837247	0.844453	0.847905	0.905363						
75	Line 45	1	0.984574	1	1						
76	Line 49	1	1	1	1						
77											
78	(time/th^2)^.5 (sec)	0	0	0	0						
79	From: Line 12	46.42308	44.63757	45.13355	46.42308						
80	Line 16	63.37449	60.93701	61.61409	63.37449						
81	Line 20	80.77179	77.66518	78.52813	80.77179						
82	Line 24	91.78502	88.25483	89.23544	91.78502						
83	Line 28	167.3808	160.9431	162.7313	167.3808						
84	Line 32	292.6027	281.3487	284.4748	292.6027						
85	Line 36	335.6383	322.7291	326.315	335.6383						
86	Line 40	443.9526	426.8775	431.6205	443.9526						
87	Line 44	692.4668	665.8334	673.2316	692.4668						
88	Line 48	774.2172	744.4396	752.7111	774.2172						
89											
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	A	B	C	D	E	F	G	H	I	J	K
1	Moisture Absorption in Honeycomb at 22 Deg.C and 80% RH										
2											
3	Sample #	1	2	3							
4	Thickness (cm)	2.3	2.3	2.15							
5	Length (cm)	5	5	5							
6	Width (cm)	5	5	5							
7	Start: 7-11 0730										
8	Dry Weight a,t t=0	3.47701	3.54511	3.43841							
9	Wt at t=inf	3.687	3.7531	3.637							
10											
11	Time out	1410	1410	1410							
12	Min	390	390	390							
13	Weight (Grams)	3.5677	3.63945	3.5313							
14	Time in										
15	Time out 7-12	1030	1030	1030							
16	Min	1620	1620	1620							
17	Weight	3.6255	3.694	3.582							
18	Time in										
19	Time out 7-13	810	810	810							
20	Min	2920	2920	2920							
21	Weight	3.6436	3.7126	3.5992							
22	Time in										
23	Time out 7-14	1350	1350	1350							
24	Min	4700	4700	4700							
25	Weight	3.6544	3.7223	3.6096							
26	Time in										
27	Time out 7-15	1425	1425	1425							
28	Min	6175	6175	6175							
29	Weight	3.6601	3.7278	3.6146							
30	Time in										
31	Time out 7-20	1345	1345	1345							
32	Min	13335	13335	13335							
33	Weight	3.6731	3.7417	3.6265							
34	Time in										
35	Time out 7-22	1420	1420	1420							
36	Min	16250	16250	16250							
37	Weight	3.6736	3.7426	3.6276							
38	Time in										
39	Time out 7-25	705	705	705							
40	Min	20135	20135	20135							
41	Weight	3.6791	3.7478	3.6328							
42	Time in										
43	Time out 7-29	735	735	735							
44	Min	25925	25925	25925							
45	Weight	3.6802	3.7481	3.634							
46	Time in										
47	Time out 8-5	1340	1340	1340							
48	Min	36370	36370	36370							
49	Weight	3.683	3.751	3.6363							
50	Time in										
51	Time out 9-7	645	645	645							
52	Min	82875	82875	82875							
53	Weight	3.687	3.7531	3.637							
54											
55	Regression Analysis: using the first 2 points										
56	b (intersection)	0	0	0							
57	a (x-coeff)	0.006494	0.00682	0.006574							
58											
59	D=x^2*Pi/16	8.28E-06	9.13E-06	8.49E-06							
60	D(corr. R&M)	1.01E-05	1.12E-05	1.02E-05							
61											
62	22C,80RH Sorb.	6.039384	5.866955	5.775635							
63											

	A	B	C	D	E	F	G	H	I	J	K
64											
65											
66	Mt/M(inf)	0	0	0							
67	From: Line 13	0.431878	0.453579	0.467748							
68	Line 17	0.707129	0.715852	0.723047							
69	Line 21	0.793323	0.805279	0.809658							
70	Line 25	0.844755	0.851916	0.862027							
71	Line 29	0.871899	0.87836	0.887205							
72	Line 33	0.933806	0.94519	0.947127							
73	Line 37	0.936187	0.949517	0.952666							
74	Line 41	0.962379	0.974518	0.978851							
75	Line 45	0.967618	0.97596	0.984893							
76	Line 49	0.980951	0.989903	0.996475							
77	Line 53	1	1	1							
78											
79	(time/th^2)^.5 (sec)	0	0	0							
80	From: Line 12	66.50895	66.50895	71.14911							
81	Line 16	135.5518	135.5518	145.0089							
82	Line 20	181.9865	181.9865	194.6833							
83	Line 24	230.8855	230.8855	246.9938							
84	Line 28	264.6466	264.6466	283.1103							
85	Line 32	388.9057	388.9057	416.0386							
86	Line 36	429.3134	429.3134	459.2655							
87	Line 40	477.8852	477.8852	511.2261							
88	Line 44	542.2595	542.2595	580.0916							
89	Line 48	642.2727	642.2727	687.0824							
90	Line 52	969.5262	969.5262	1037.168							
91											
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	A	B	C	D	E	F	G	H	I	J	K
1	Moisture Absorption in Honeycomb at 50 Deg.C and 80% RH										
2											
3	Sample #	1	2	3							
4	Thickness (cm)	2.3	2.3	2.15							
5	Length (cm)	5	5	5							
6	Width (cm)	5	5	5							
7	Start:										
8	Dry Weight a,t t=0	3.49001	3.55285	3.45005							
9	Wt at t=inf	3.6449	3.7075	3.5951							
10											
11	Time out	825	825	825							
12	Min	85	85	85							
13	Weight (Grams)	3.56537	3.6265	3.534							
14	Time in										
15	Time out	1047	1047	1047							
16	Min	227	227	227							
17	Weight	3.5926	3.6561	3.5539							
18	Time in										
19	Time out	645	645	645							
20	Min	1425	1425	1425							
21	Weight	3.6252	3.684	3.5799							
22	Time in										
23	Time out	750	750	750							
24	Min	2930	2930	2930							
25	Weight	3.6289	3.6911	3.5869							
26	Time in										
27	Time out	655	655	655							
28	Min	4315	4315	4315							
29	Weight	3.6291	3.6938	3.5871							
30	Time in										
31	Time out	645	645	645							
32	Min	8630	8630	8630							
33	Weight	3.6449	3.7075	3.5951							
34											
35											
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50											
51											
52	Regression Analysis: using the first 2 points										
53	b (intersection)	0	0	0							
54	a (x-coeff)	0.01567	0.015338	0.017424							
55											
56	D=x^2*Pi/16	4.82E-05	4.62E-05	5.96E-05							
57	D(corr. R&M)	5.9E-05	5.65E-05	7.15E-05							
58											
59	35C,80RH Sorb.	4.438096	4.352843	4.204287							
60											
61											
62											
63											

	A	B	C	D	E	F	G	H	I	J	K
64											
65											
66	Mt/M(inf)	0	0	0							
67	From: Line 13	0.486539	0.476237	0.578766							
68	Line 17	0.662341	0.667637	0.71596							
69	Line 21	0.872813	0.848044	0.895209							
70	Line 25	0.896701	0.893954	0.943468							
71	Line 29	0.897992	0.911413	0.944847							
72	Line 33	1	1	1							
73											
74	(time/th^2)^.5 (sec)	0	0	0							
75	From: Line 12	31.04969	31.04969	33.21595							
76	Line 16	50.7412	50.7412	54.28128							
77	Line 20	127.1321	127.1321	136.0018							
78	Line 24	182.2979	182.2979	195.0163							
79	Line 28	221.227	221.227	236.6615							
80	Line 32	312.8623	312.8623	334.6899							
81											
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REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE 1 October 1994	3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE Sorption and Diffusion of Moisture in Multilayer Composite AEM/S Sandwich Materials	5. FUNDING NUMBERS
6. AUTHOR(S) Dr. Joseph M. Augl	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Surface Warfare Center Carderock Division, White Oak Laboratory 10901 New Hampshire Ave. Silver Spring, MD 20903-5640	8. PERFORMING ORGANIZATION REPORT NUMBER CDNSWC/TR-94/___
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of Naval Research	10. SPONSORING/MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES	
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.	12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The moisture diffusion coefficients and solubilities of Advanced Enclosed Mast/Sensor (AEM/S) sandwich constituent materials of interest have been determined at 22, 35, and 50°C and at 80 percent relative humidity. Expressions for calculating the diffusion coefficients and solubilities for any temperature of interest to marine environments are provided. The objective of this study was to provide input data for finite element moisture diffusion analyses that permits one to predict the moisture take-up and internal distribution as a function of time for composite mast sandwich structures in specified marine environments. The following materials were included in this investigation: E-glass/SP Systems 3113 epoxy, E-glass/510A vinyl-ester (RTM3), E-glass/G10 epoxy, Balsa wood type D57, PVC foam (Klegecell), and Nomex honeycomb phenolic core material.

14. SUBJECT TERMS moisture diffusion coefficients AEM/S marine environment solubility	15. NUMBER OF PAGES 76
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR